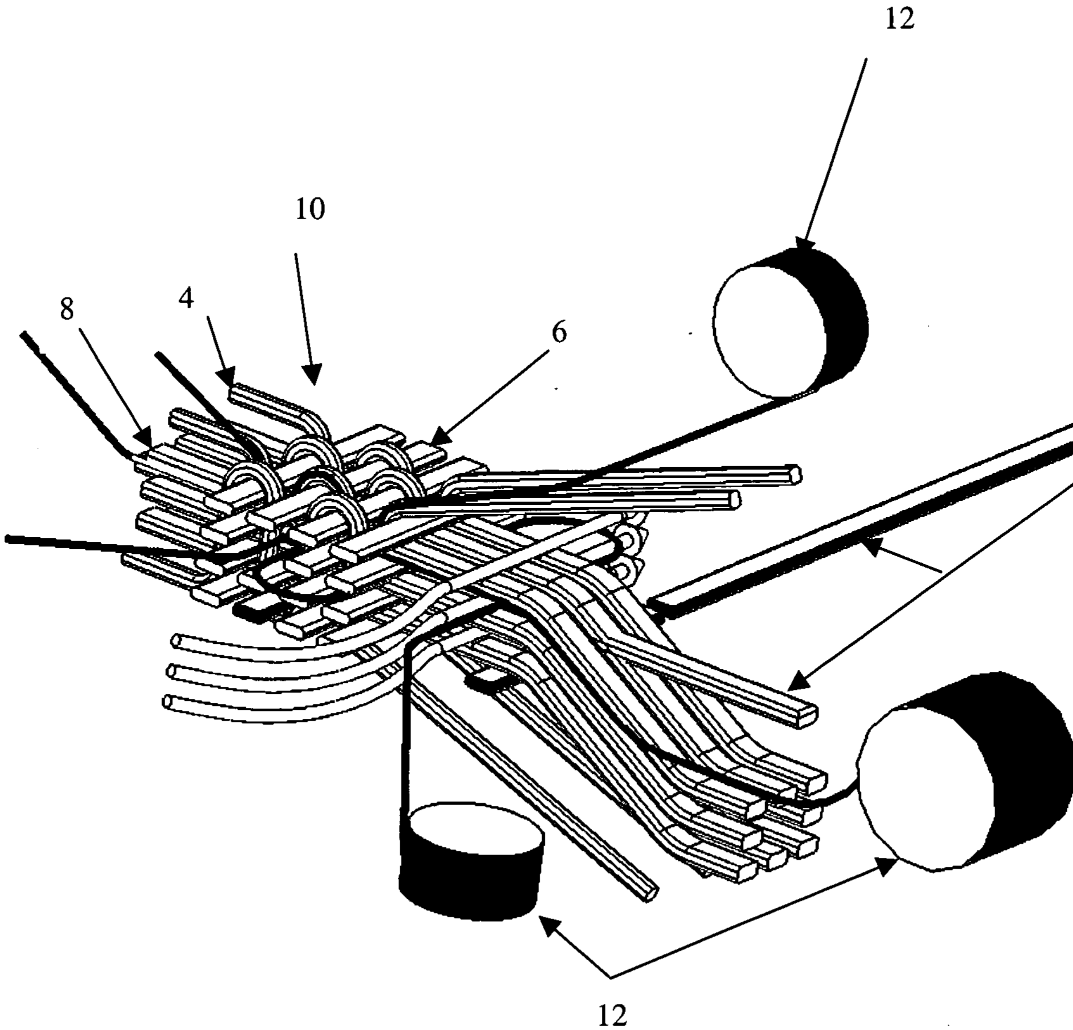

Fig. 1

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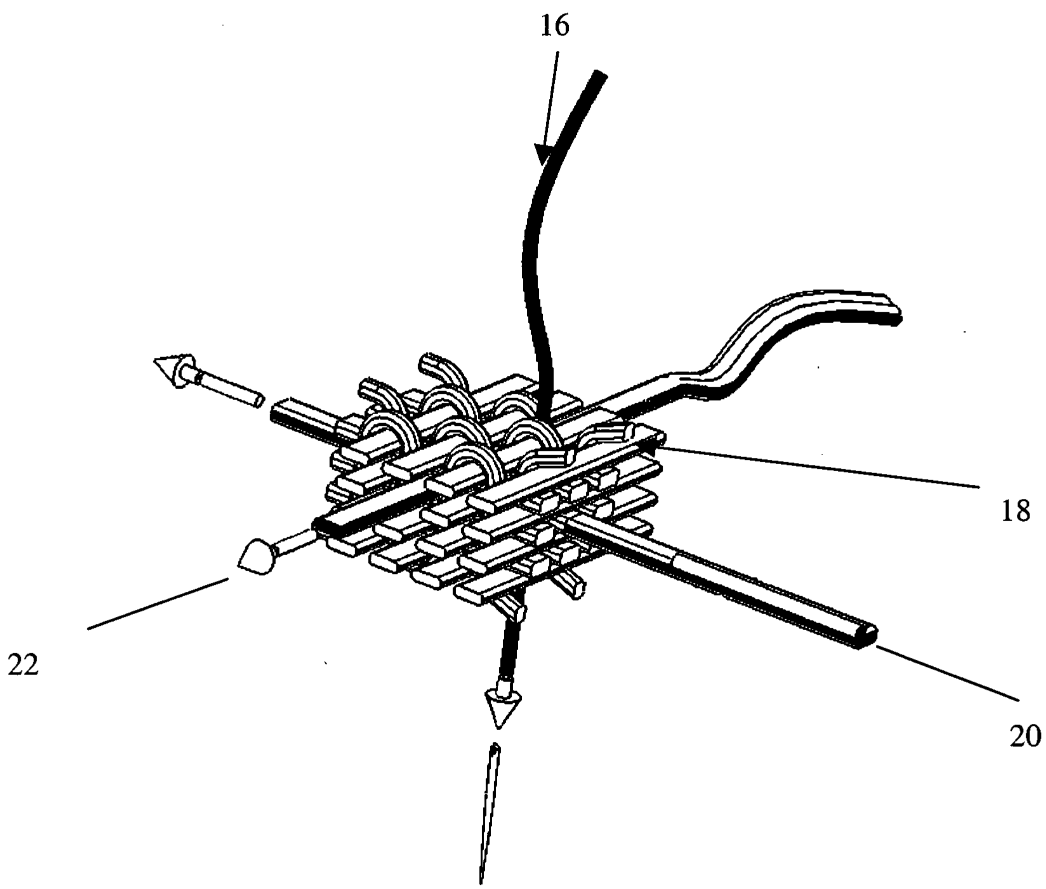


Fig. 2

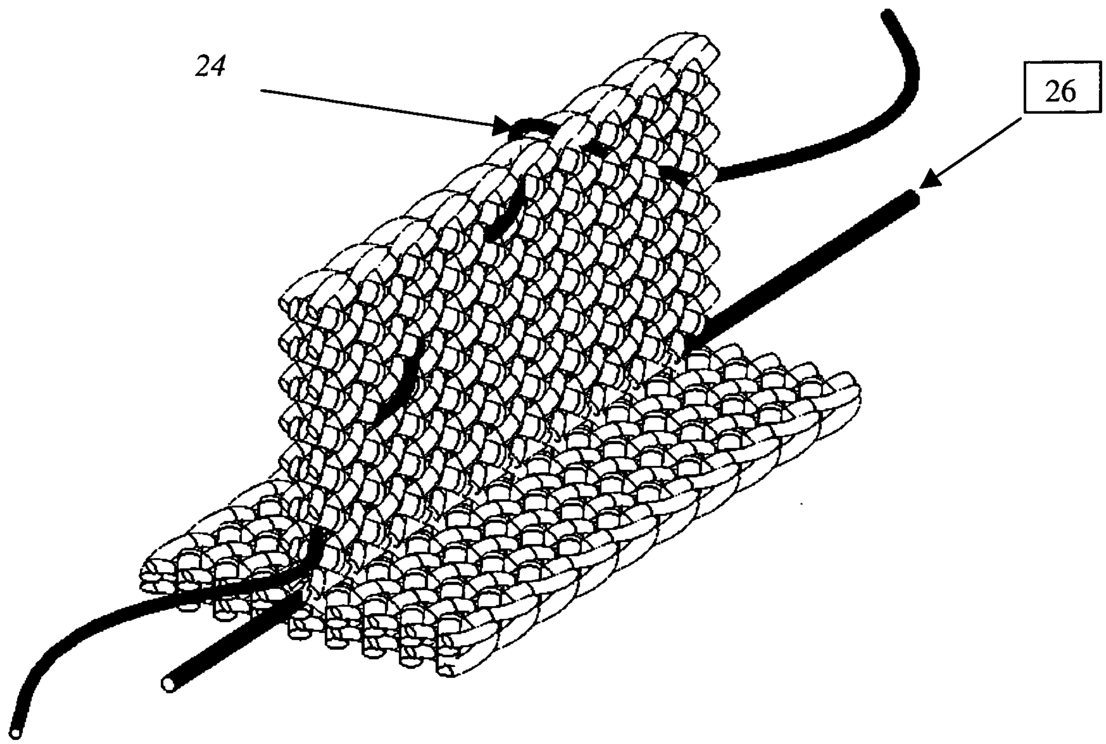


Fig. 3

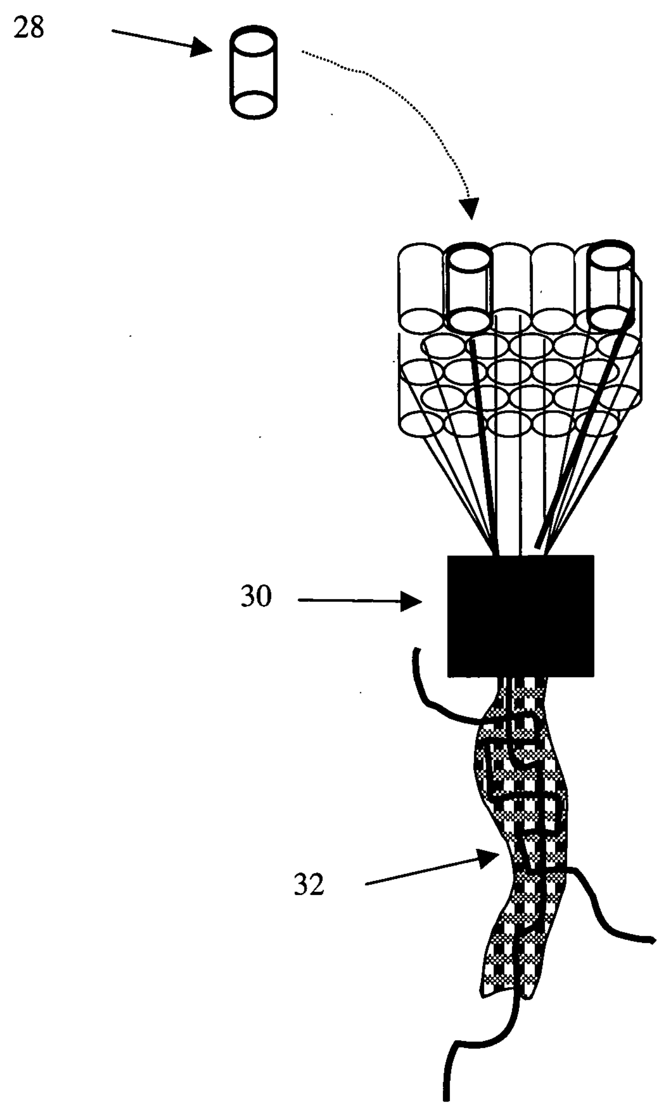


Fig. 4

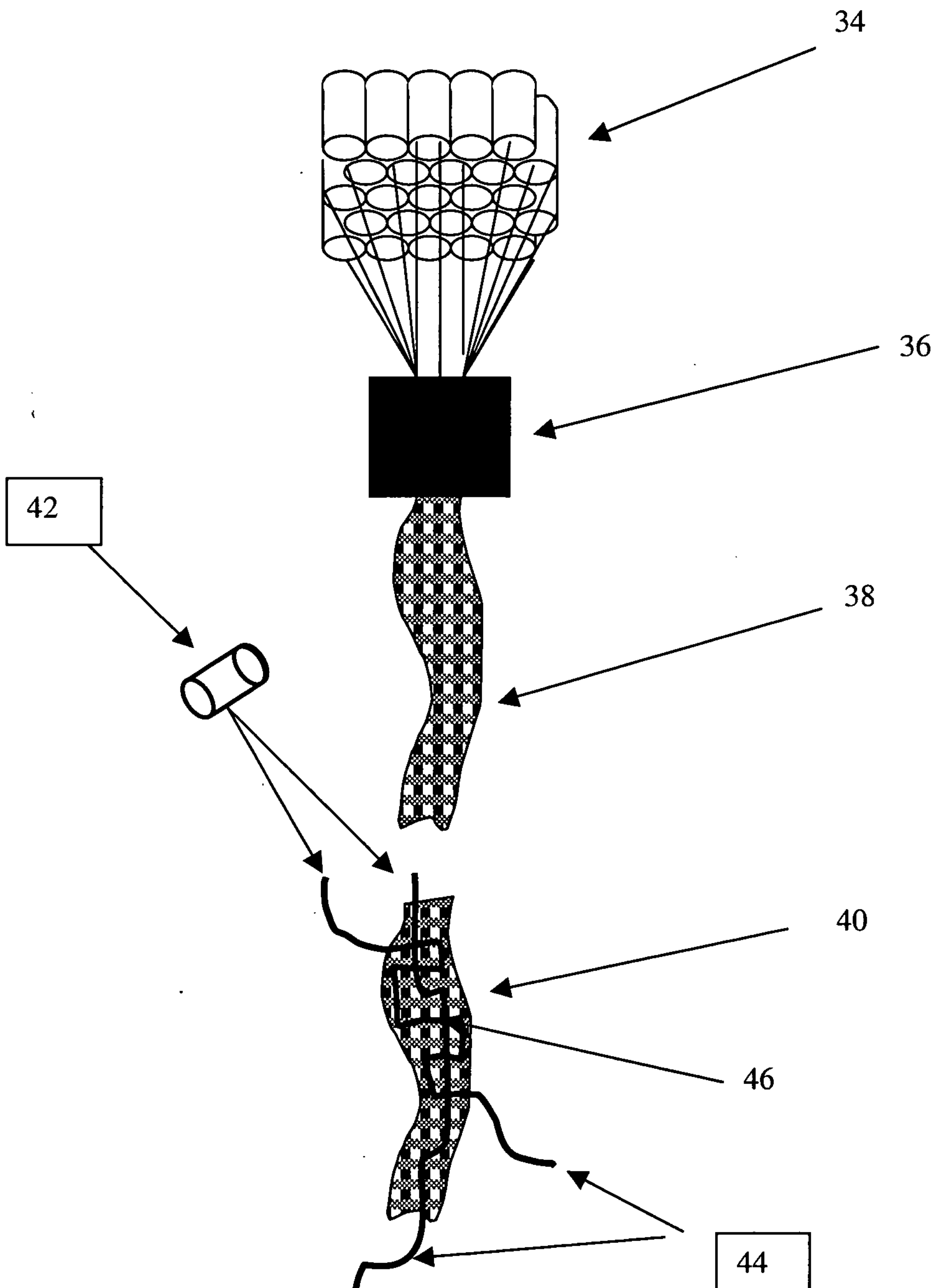


Fig. 5

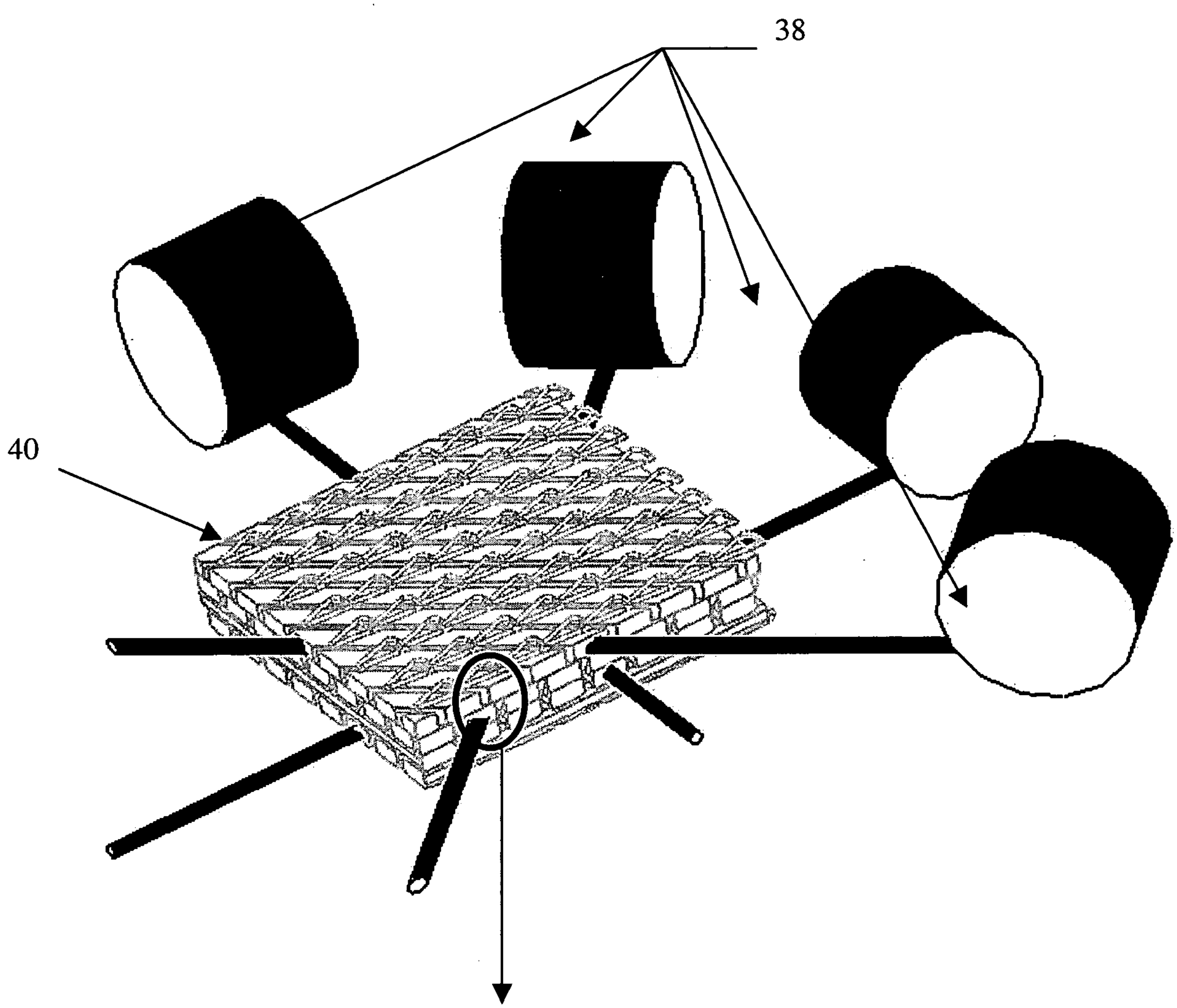


Fig. 6

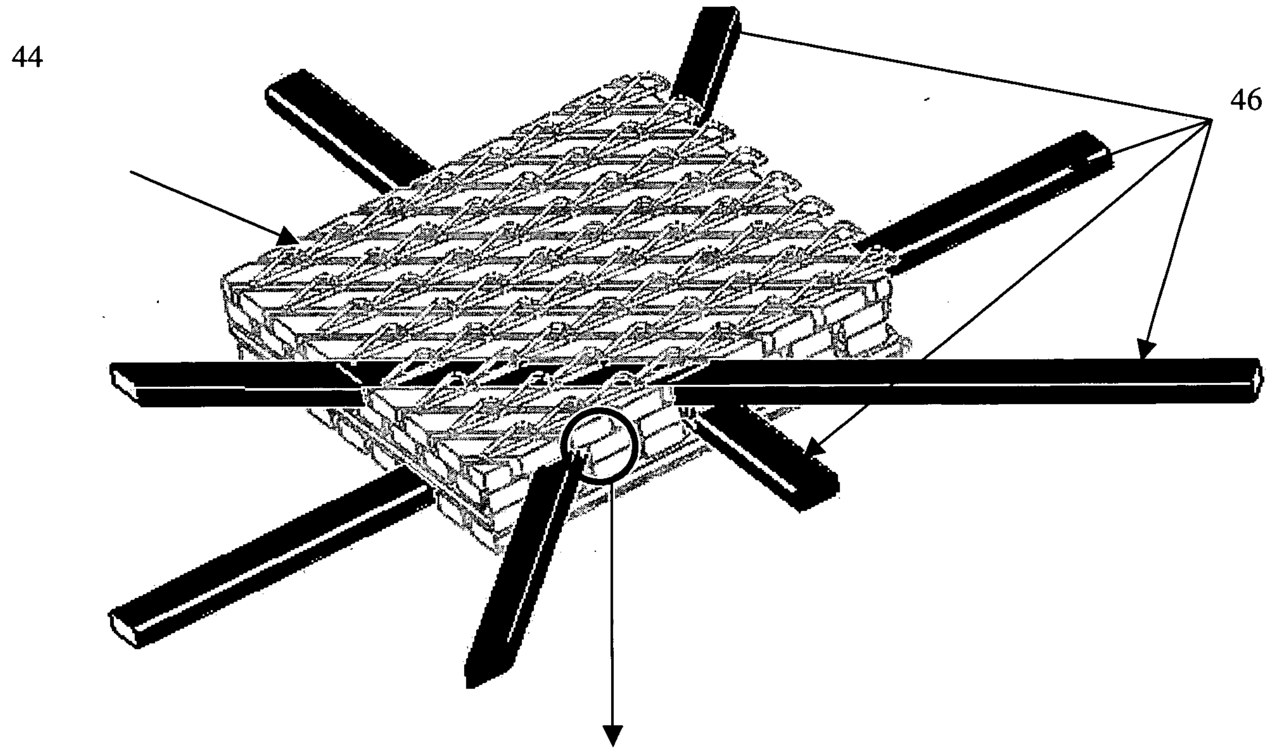


Fig. 7

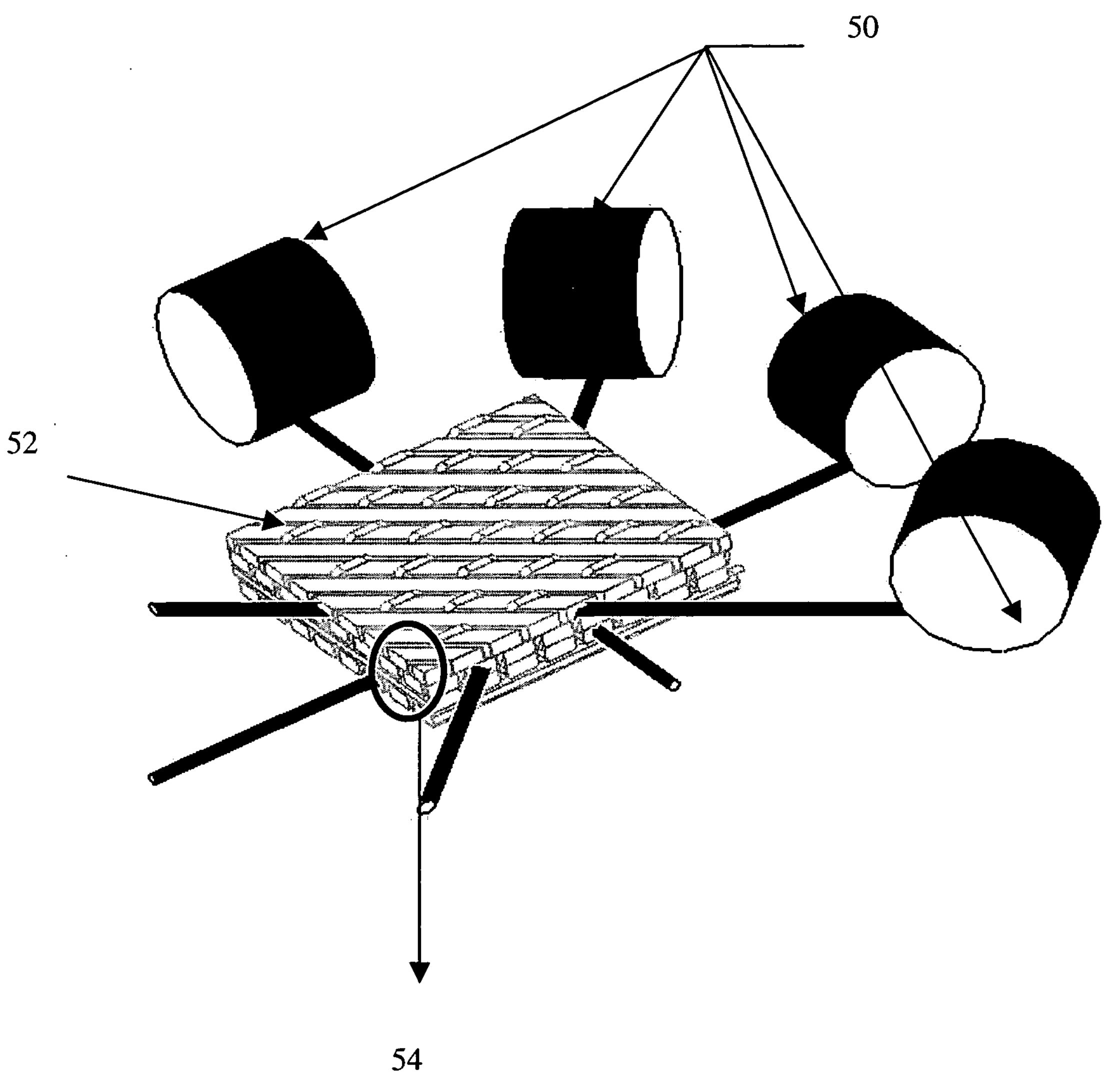


Fig. 8

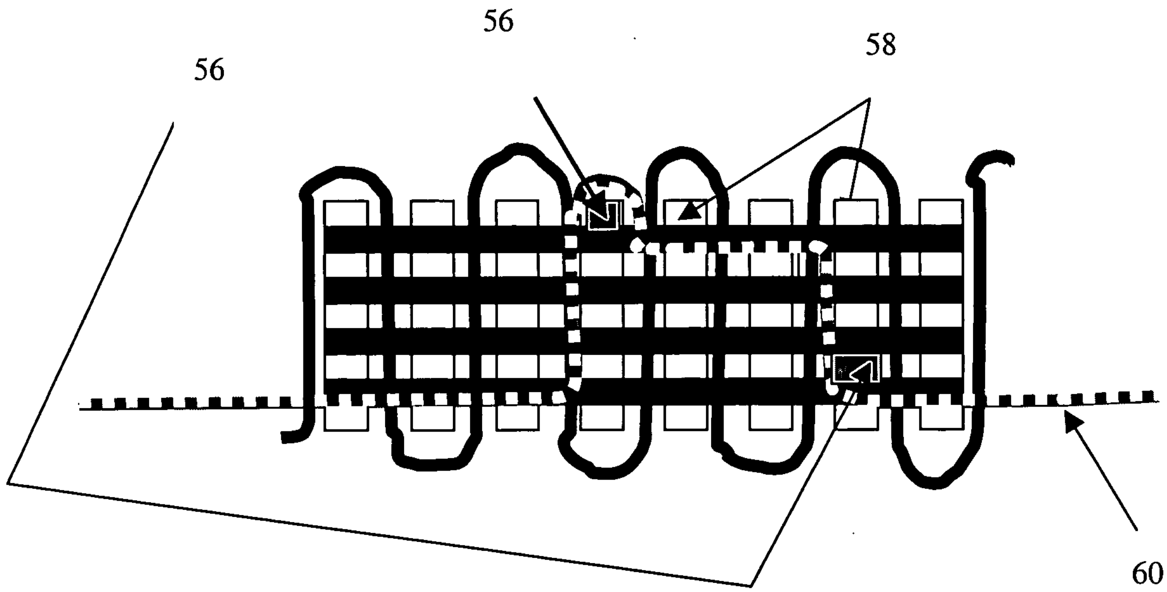


Fig. 9

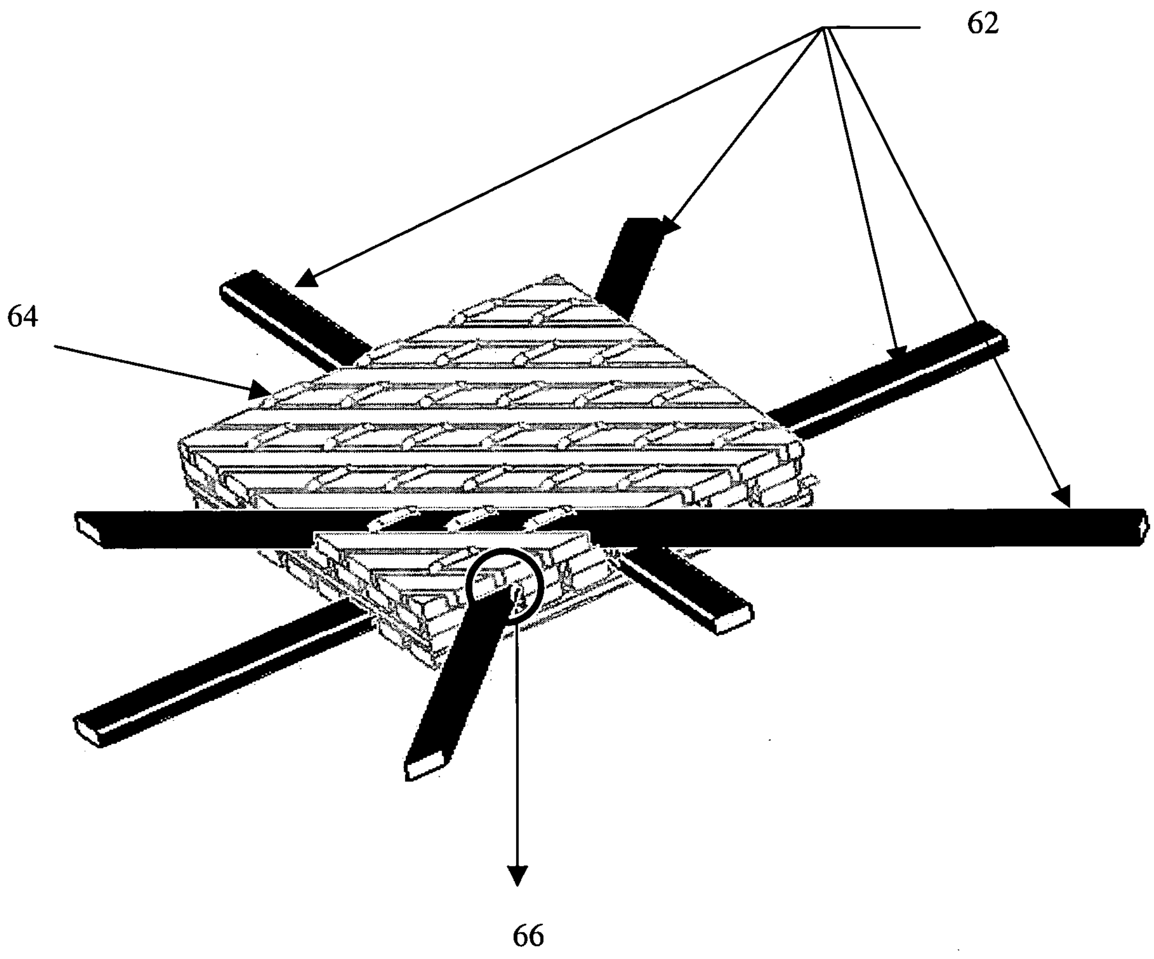


Fig. 10

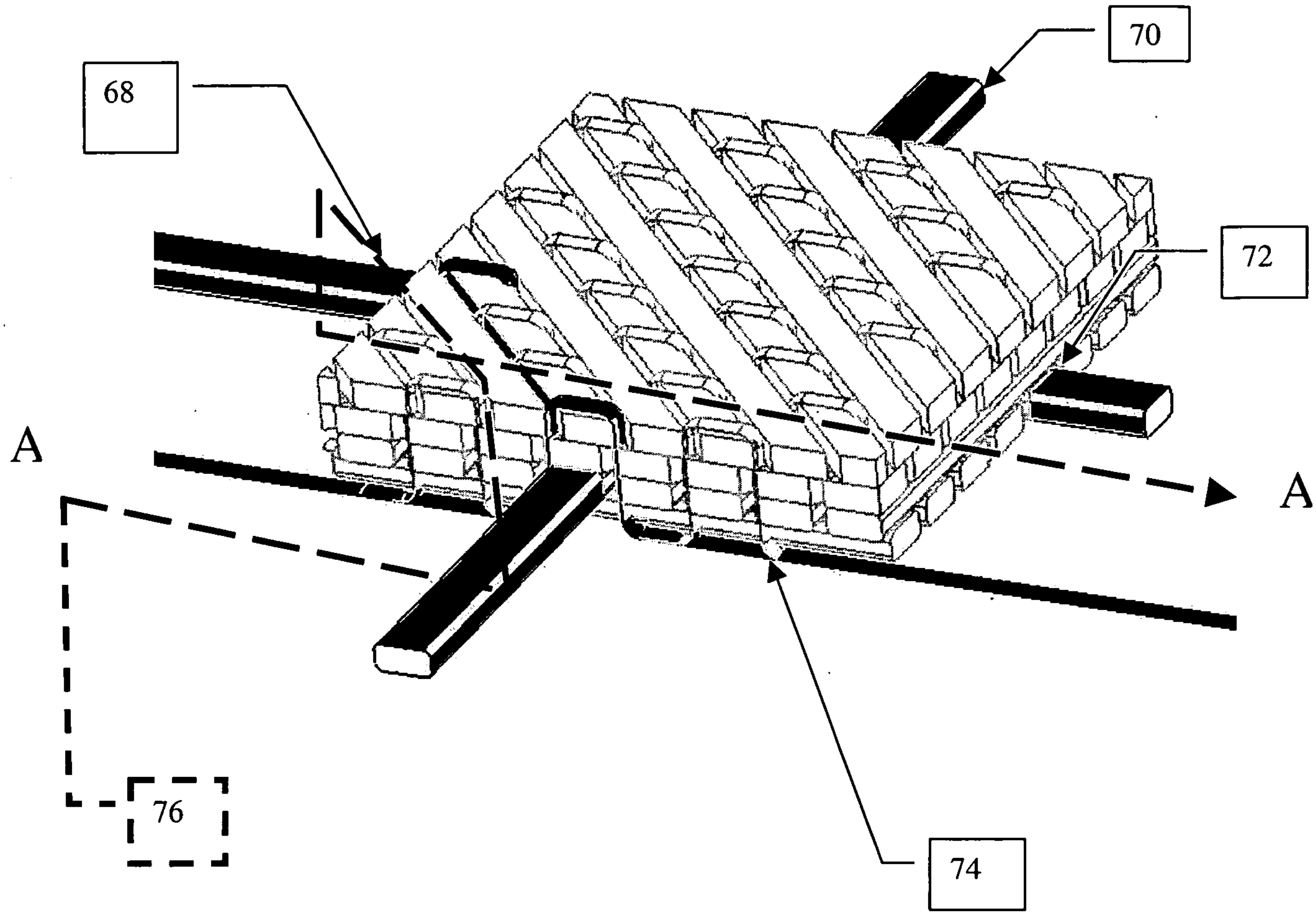


Fig. 11

FIG. 12 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by addition of one or more system/device materials to normal process supply during the formation of a 3-D orthogonal woven fabric/preform. Continuous supplies of relatively smaller flexible system/device materials are shown to be added to the relatively larger normal host material supply lines so as to merge into the normal host materials. In this particular embodiment merging of host and system/device materials may be performed at any step prior to and including the moment of fabric formation, such as but not limited to co-winding/commingling of a smaller optical fiber with a larger carbon yarn onto a standard spool subsequently added to the normal creels or other supply system when convenient, or by co-insertion with the host material in the filling direction as with a plaid. This addition method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device.

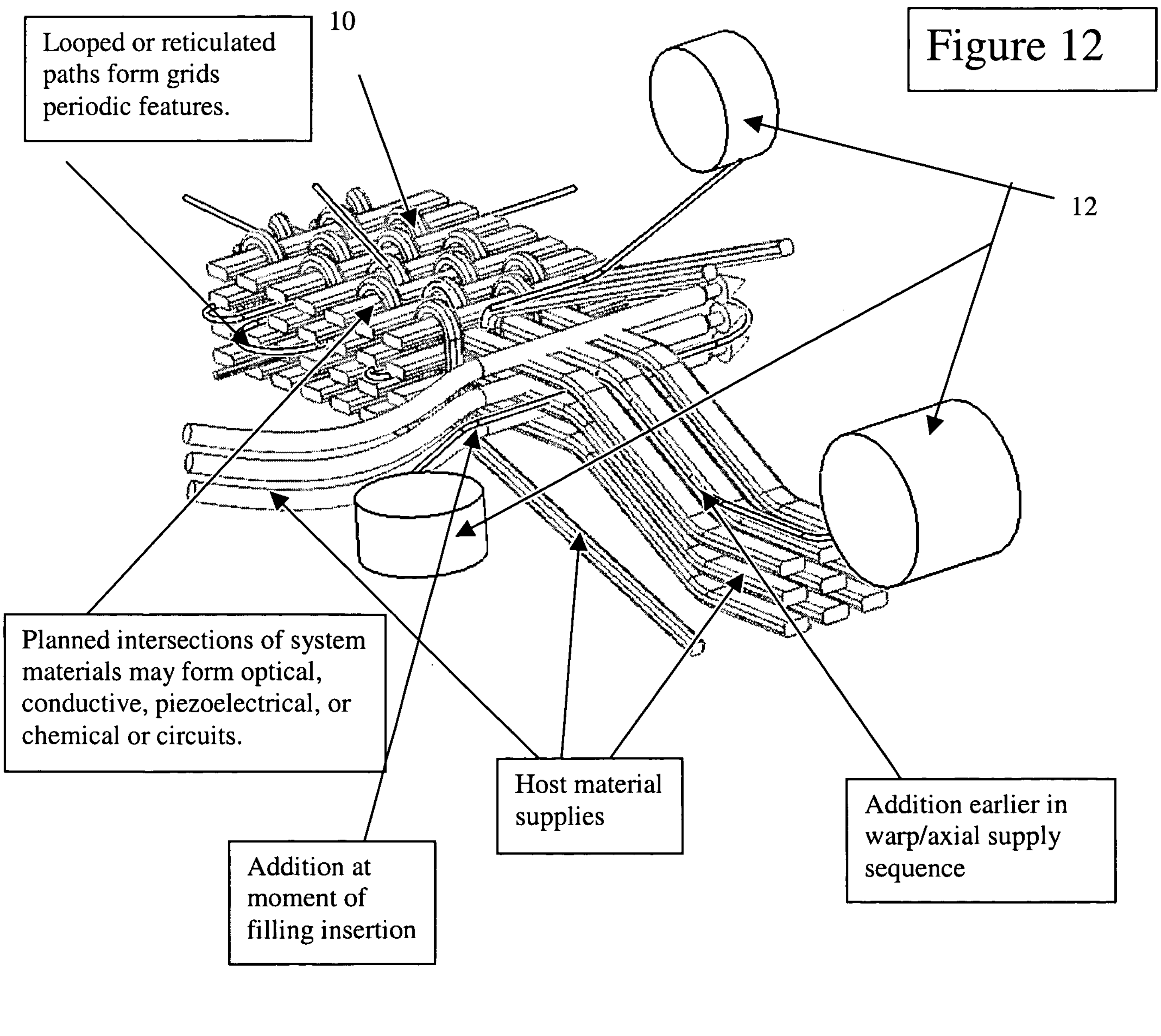
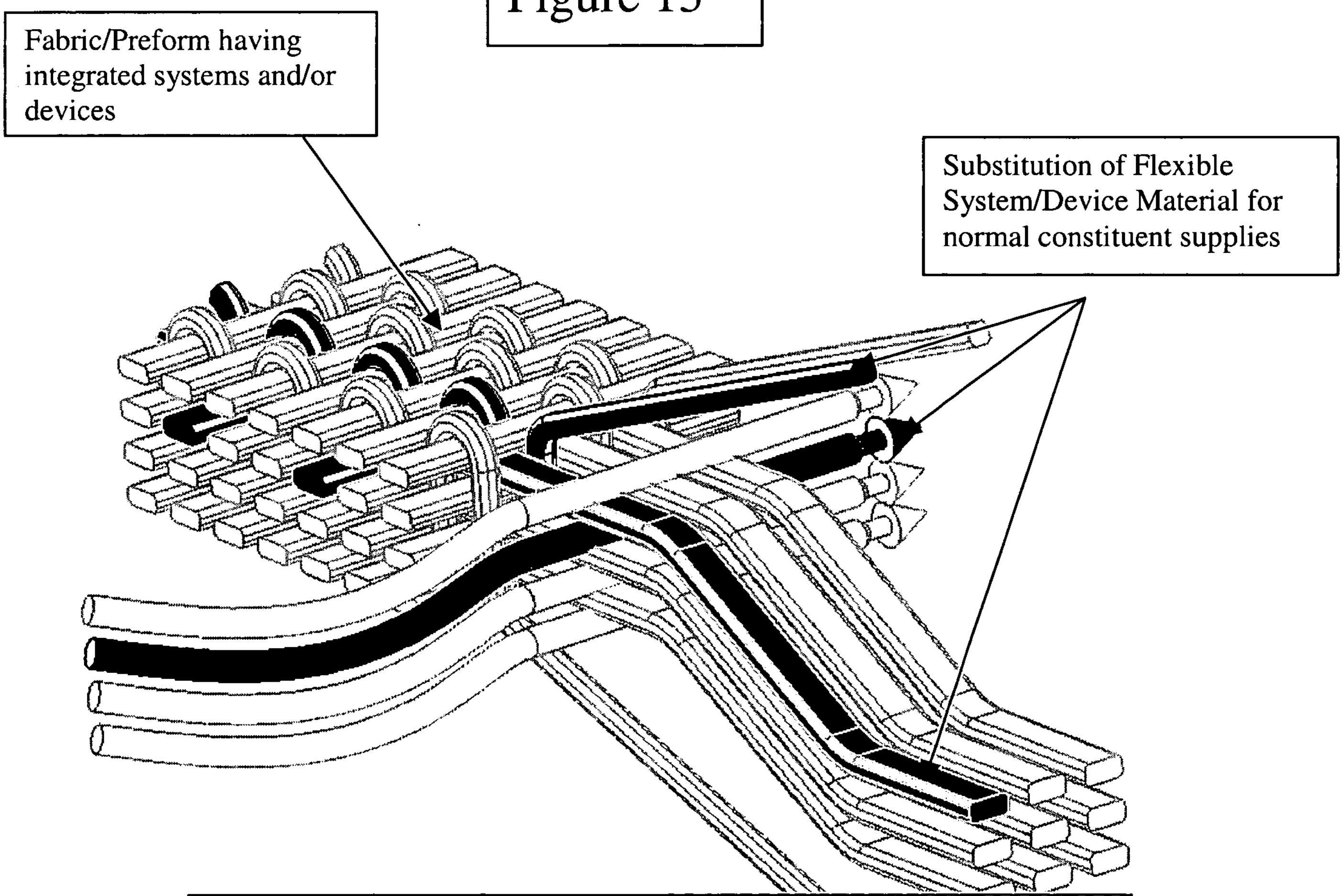


Figure 12

FIG. 13 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by the substitution of one or more system/device materials for host materials during the formation of a 3-D orthogonal woven fabric/preform. Continuous supplies of flexible system/device materials are shown to be substituted at preferred locations in the regular host material supply lines so as to be integrated in the fabric along with the regular host materials. In this particular embodiment, substitution of system/device materials for the host materials may be performed at any step prior to or at the moment of fabric formation, such as but not limited to use of a color picker to substitute as with weaving a plaid fabric, or used of a jacquard, dauby, or other heddle controls to add the system/device materials to the warp/axials when and where desired (as with plaids, jacquard upholstery etc.) to perform as desired or form circuits/junctures. This substitution method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device.

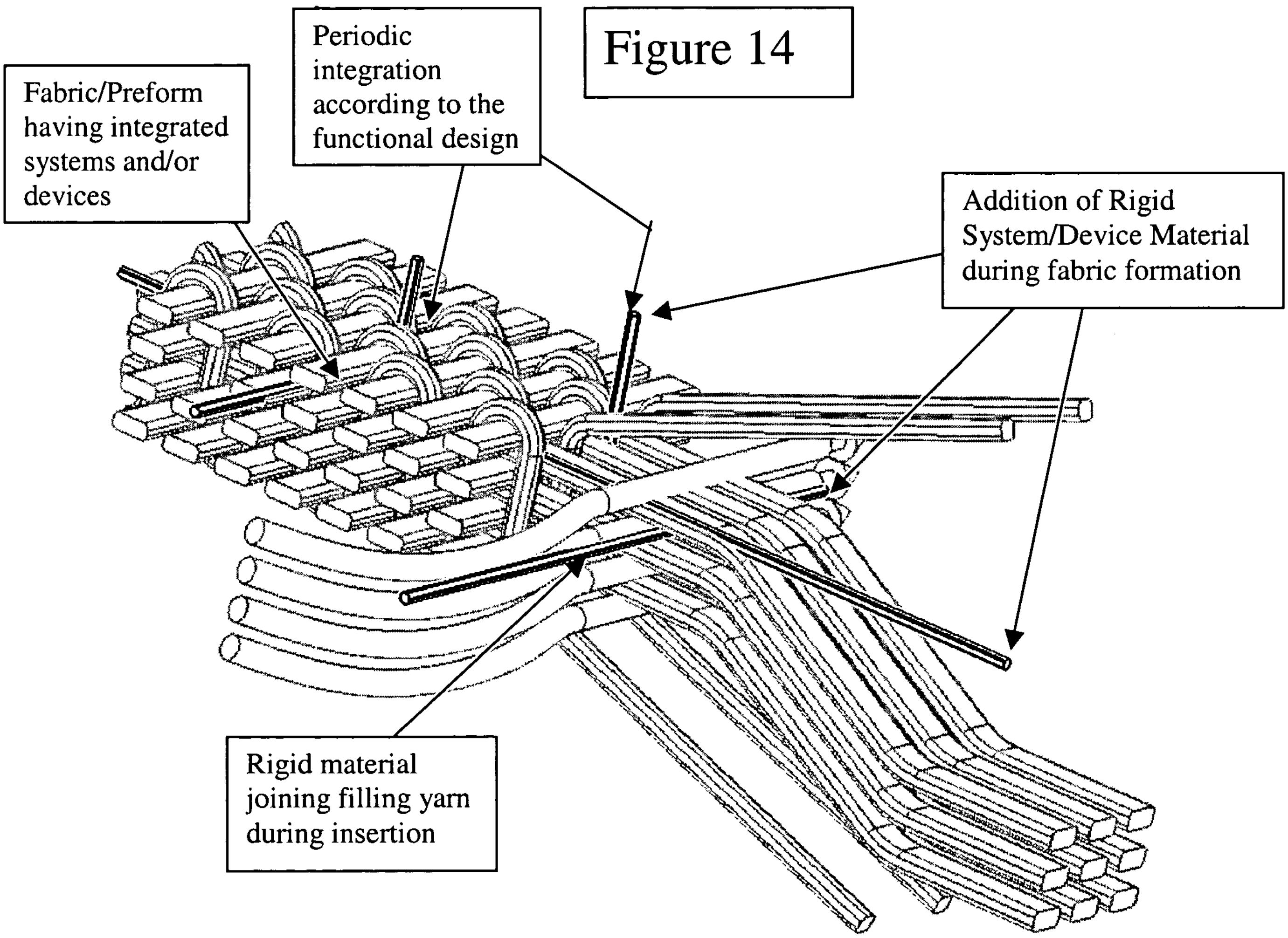
Figure 13



Flexible System/Device Materials Joining Host Material in Fabric Formation Process by Substitution

FIG. 14 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by addition of one or more system/device materials to host materials during the formation of a 3-D orthogonal woven fabric/preform. This and several other 3-D fabric architectures have a useful array of uncrimped yarn paths which readily accommodate less flexible system/device materials. Supplies of rigid system/device materials are shown to be added at preferred locations to the regular host material supply lines so as to be incorporated in the regular host materials. In this particular embodiment, addition of system/device materials for the host materials may be performed at any step prior to or at the moment of fabric formation, such as but not limited to addition of the rigid system/device materials to the warp/axial yarns prior to weaving, use of a color picker to add the rigid materials on demand to the filling yarn, or adding the system/device materials to the warp/axial yarn when and where desired (as with plaids) to perform as desired or form circuits/junctures. This addition method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device.

Figure 14



Rigid System/Device Materials Joining Host Material in Fabric Formation Process by Addition

FIG. 15 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by substitution of one or more system/device materials for host material yarns during the formation of a 3-D orthogonal woven fabric/preform. This and several other 3-D fabric architectures have a useful array of uncrimped yarn paths which readily accommodate less flexible system/device materials. Supplies of rigid system/device materials are shown to be substituted at preferred locations in the regular host material supply lines so as to be interwoven with the host materials. In this particular embodiment, substitution of system/device materials for the host materials may be performed at any step prior to or at the moment of fabric formation, such as but not limited to addition of the rigid system/device materials to the warp/axial yarns prior to weaving, use of a color picker to substitute the rigid materials on demand to the filling yarn, or adding the system/device materials to the warp/axial yarn when and where desired (as with plaids) to perform as desired or form circuits/junctures. This substitution method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device.

Figure 15

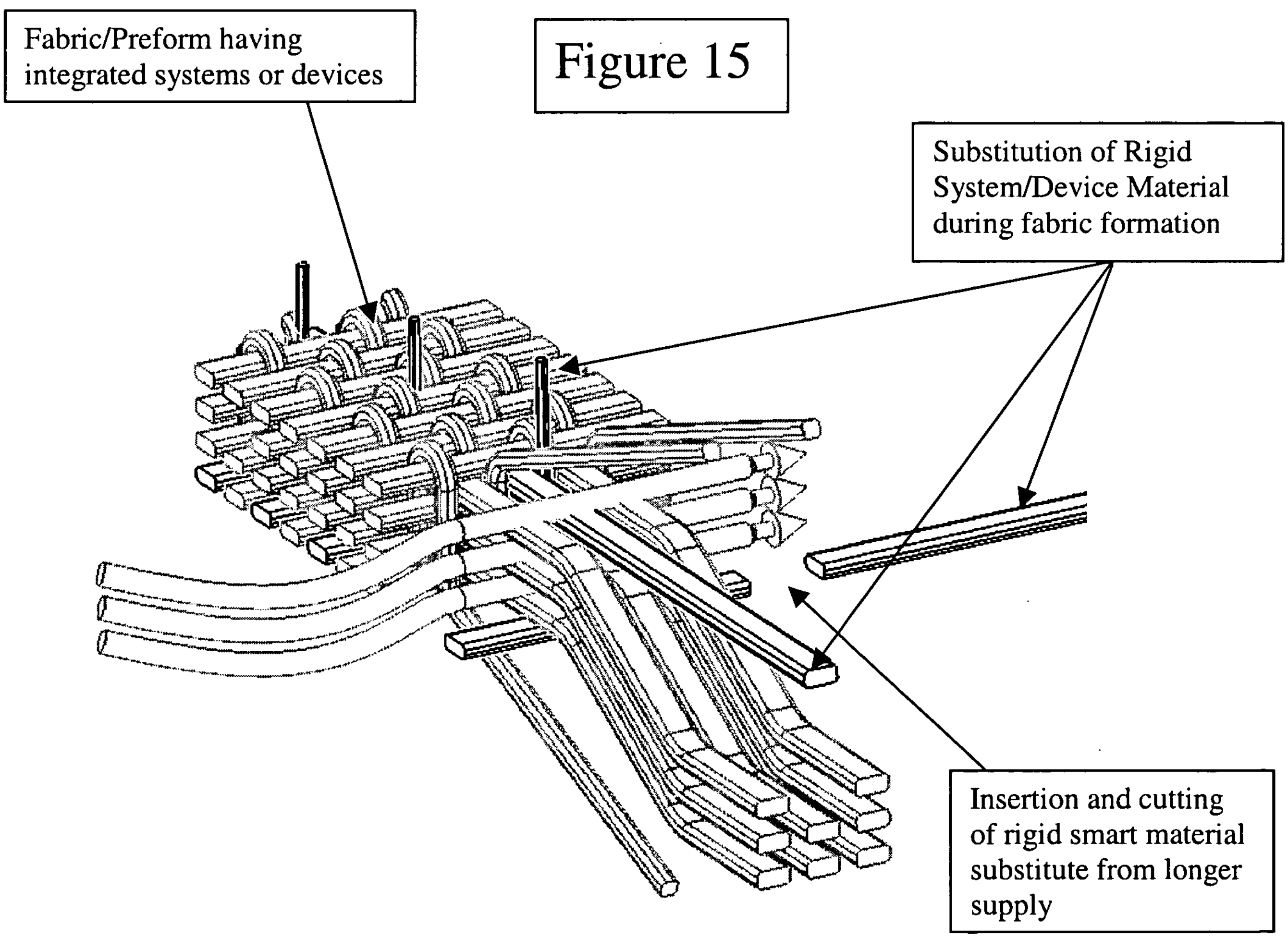
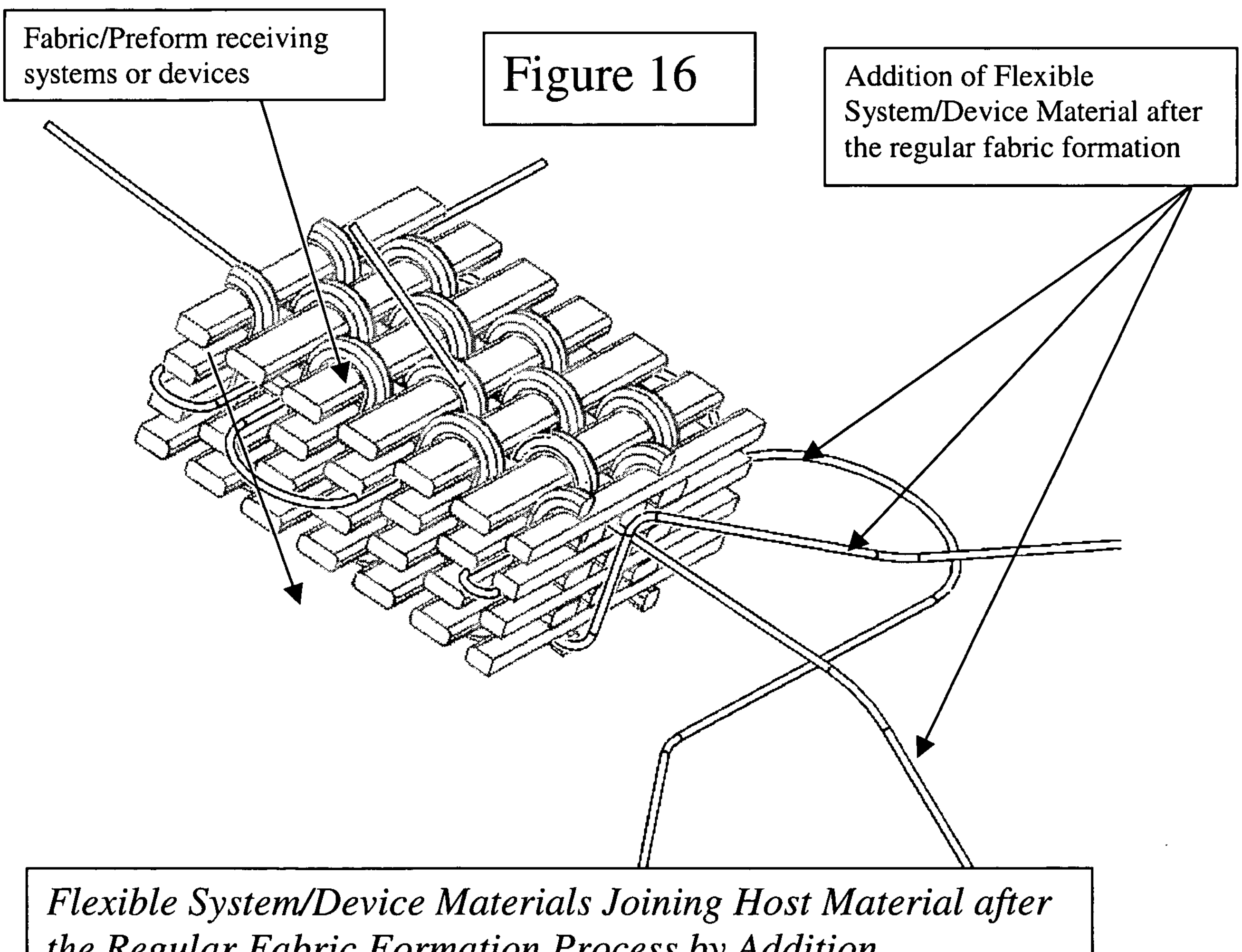


FIG. 16 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by addition of one or more system/device materials to host yarns after the formation of a 3-D orthogonal woven fabric/preform. Supplies of flexible system/device materials are shown to be added at preferred locations, which may be separated from the regular host fiber supply locations. In this particular embodiment, addition of system/device materials to the host materials may be performed after weaving, by means including but not limited to insertion with a needle as if embroidery, or by attaching the system/device material to the warp or weft and pulling it in along with additional host material, when and where desired (as with plaids) to perform as desired or form circuits/junctures. This addition method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device. In particular, yarn paths which are straight by nature may be preferred due to the ease with which they may be bulled through or followed with a needle or other suitable device.

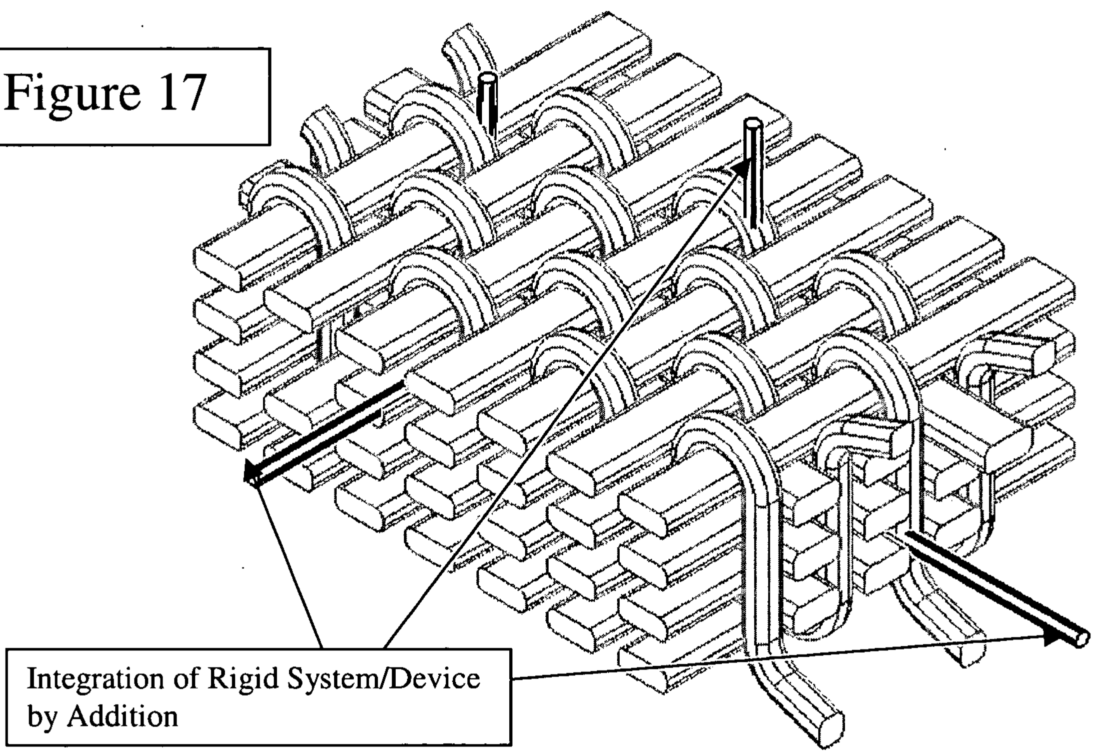
Figure 16



Flexible System/Device Materials Joining Host Material after the Regular Fabric Formation Process by Addition

FIG. 17 is a perspective illustration of one embodiment of the present invention wherein integration of system or device materials is performed by addition of one or more, relatively small, rigid system/device materials to relatively large host material yarns after the formation of a 3-D orthogonal woven fabric/preform. This and several other 3-D fabric architectures have a useful array of uncrimped yarn paths which readily accommodate less flexible system/device materials. Rigid system/device materials are shown to be added at preferred locations in the regular host material supply lines so as to be interwoven with the host materials. In this particular embodiment, addition of system/device materials to the host materials may be performed after weaving, by means including but not limited to insertion with a needle as if embroidery, or by attaching the system/device material to the warp or weft and pulling it in along with additional host material, when and where desired (as with plaids) to perform as desired or form circuits/junctures. The rigid nature of the system/device material may also be exploited by using it as its own needle during insertion, as has been done with fine but stiff optic fibers. This addition method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device. In particular, yarn paths which are straight by nature may be preferred due to the ease with which they may be pulled through or followed with a needle or other suitable device.

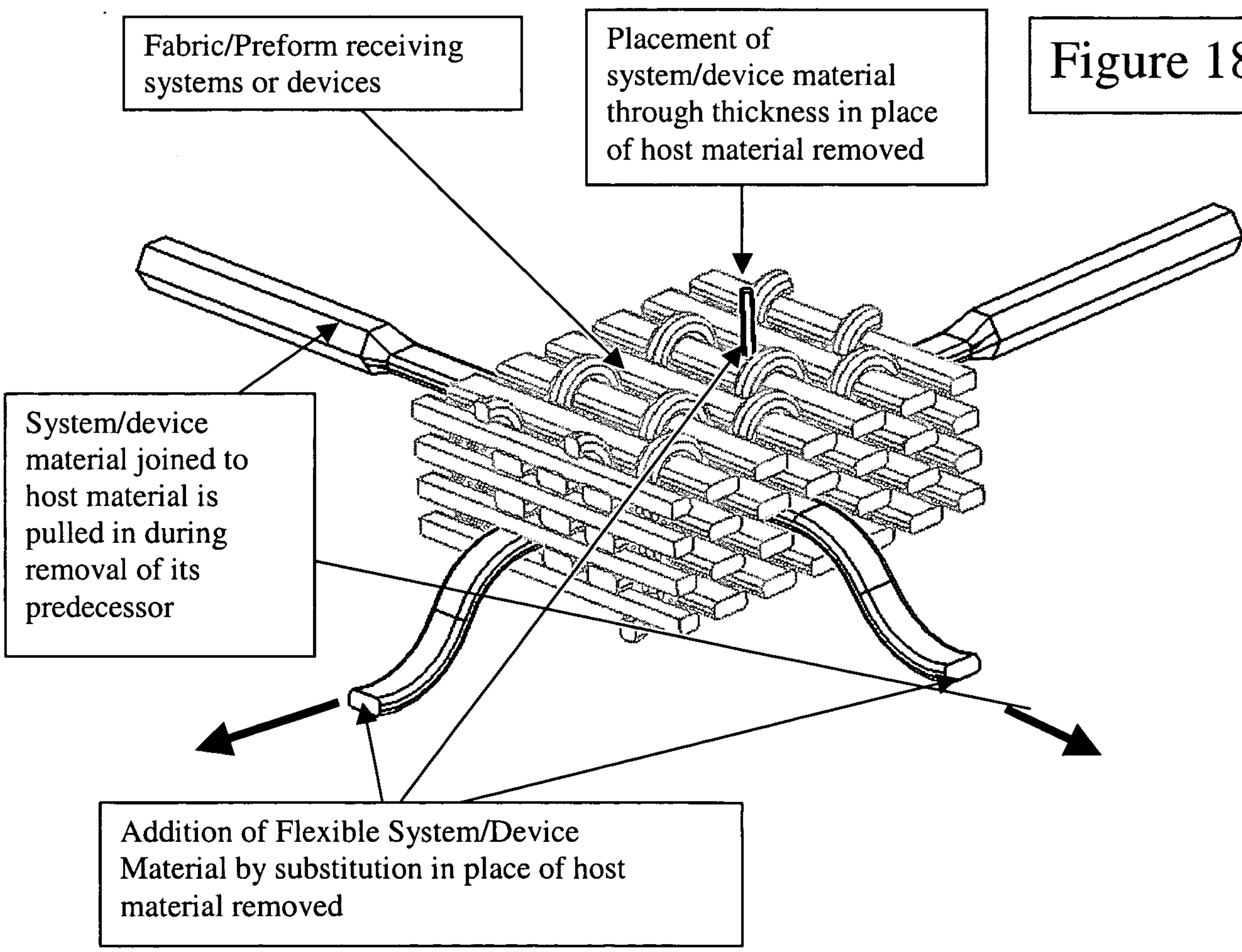
Figure 17



Rigid System/Device Materials Joining Host Material after Initial Fabric Formation Process by Addition

FIG. 18 is a perspective illustration of one embodiment of the present invention wherein integration of rigid system or device materials is performed by substitution of one or more system/device materials for host material yarns after the formation of a 3-D orthogonal woven fabric/preform. Rigid system/device materials are shown to be added at preferred locations to the regular host material supply lines so as to be interwoven with the host materials. In this particular embodiment substitution of system/device materials to the host materials may be performed after weaving, by means including but not limited to by attaching the system/device material to the warp or filling yarns and pulling it in place of the removed host material, or the use of needles, when and where desired (as with plaids) to perform as desired or form circuits/junctures. This substitution method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device. In particular, yarn paths which are straight by nature are preferred due to the ease with which they may be bulled through or followed with a needle or other suitable device and because the straight paths allow the rigid materials to remain straight.

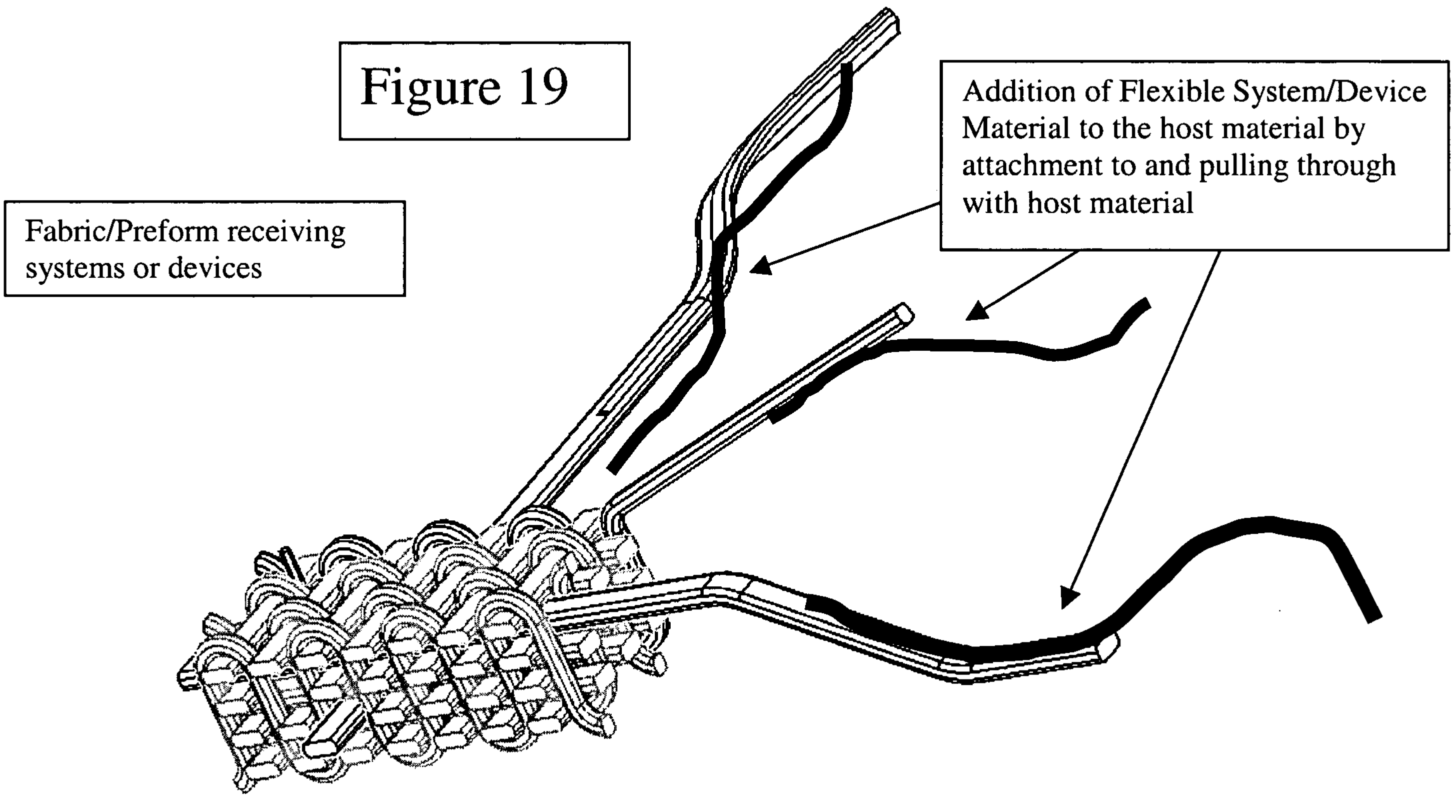
Figure 18



Rigid System/Device Materials Joining Host Material after Initial Fabric Formation Process by Substitution

FIG. 19 is a perspective illustration of one embodiment of the present invention wherein integration of flexible system or device materials is performed by addition of one or more system/device materials to host material yarns after the formation of a 3-D orthogonal woven fabric/preform. Flexible system/device materials are shown to be added at preferred locations to the normal host material supply lines so as to be interwoven with the host materials. In this particular embodiment, addition of system/device materials to the host materials may be performed after weaving, by means including but not limited to by attaching the system/device material to the warp or filling yarns and pulling it in place of the removed host material, or the use of needles, when and where desired (as with plaids) to perform as desired or form circuits/junctures. This addition method may be applied to many other fabric formation processes, including but not limited to 3-D Layer-to-Layer and Through-Thickness Interlock Weaving, 3-D Braiding, Multi-Layer Stitch Bonding and the like, in the same manner in any case wherein the system/device materials have an acceptably small effect on the process and product, and where the paths within the fabric product allow for the preferred function of the integrated system/device. In particular, yarn paths which are straight by nature are preferred due to the ease with which they may be bulled through or followed with a needle or other tool.

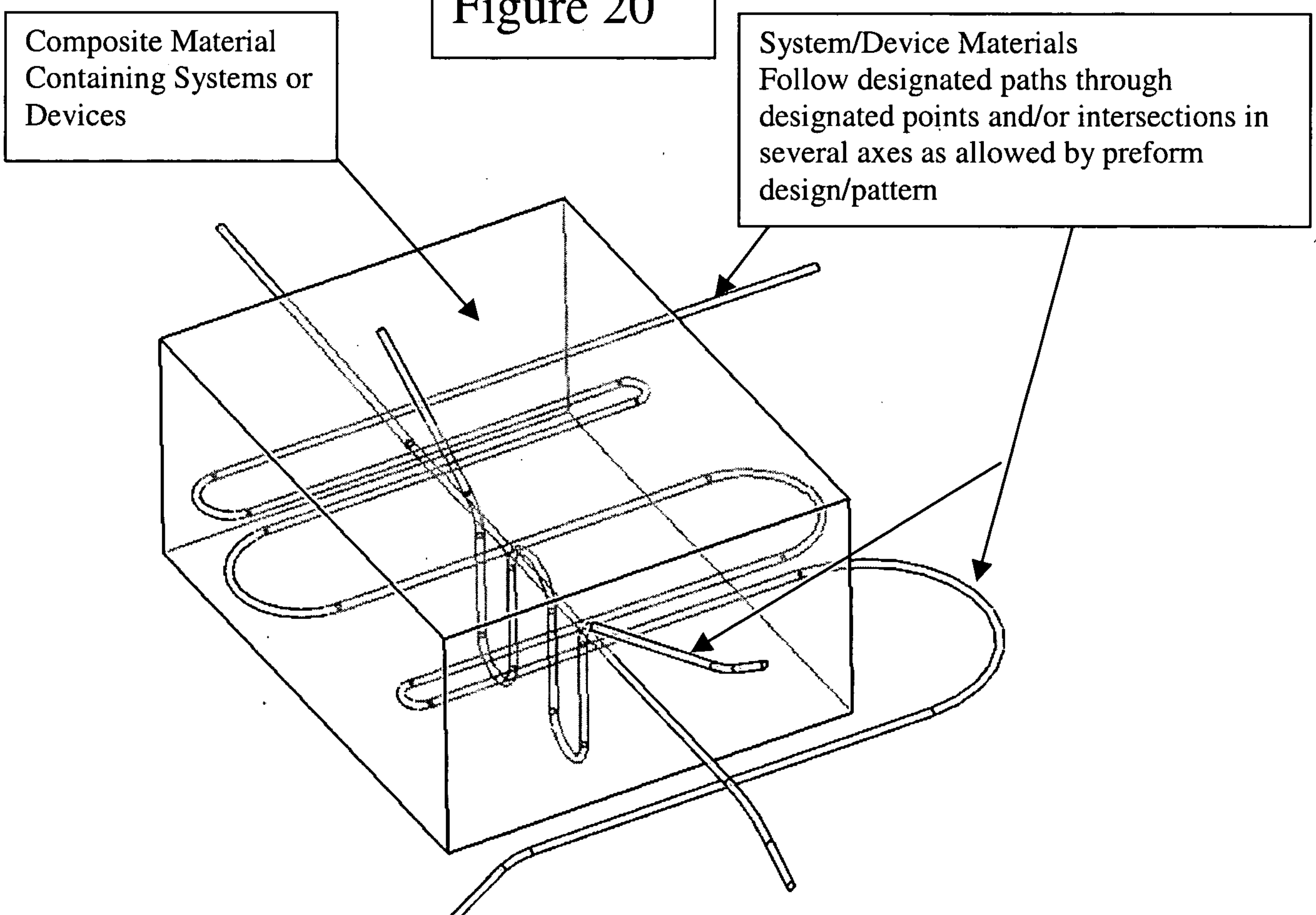
Figure 19



Flexible System/Device Materials Joining Host Material after Initial Fabric Formation Process by Addition

FIG. 20 is a perspective illustration of one embodiment of the present invention wherein integration of system/device materials in the regular host material supply lines so as to be interwoven with the host materials preform carries the functional benefit to a composite manufactured using the fabric as a preform. Note that the base fabric material is not shown for clarity. The composite may be manufactured by various means often employed with textile preforms including but not limited to Vacuum Assisted Resin Transfer Molding, Reaction Injection Molding, Resin Transfer Molding, Resin Film Infusion, Pultrusion, and Hand Lay-up. Production of various metallic, ceramic, or other inorganic and high-temperature composites may utilize the same preforms where the constituent materials are chosen for these applications. The illustration shows several of innumerable paths, intersections, or patterns which may be achieved toward achieving the desired function. In this particular embodiment the system/device materials extend considerably past the boundaries of both the preform and the subsequent composite for the convenience of connecting to the system or devices integrated.

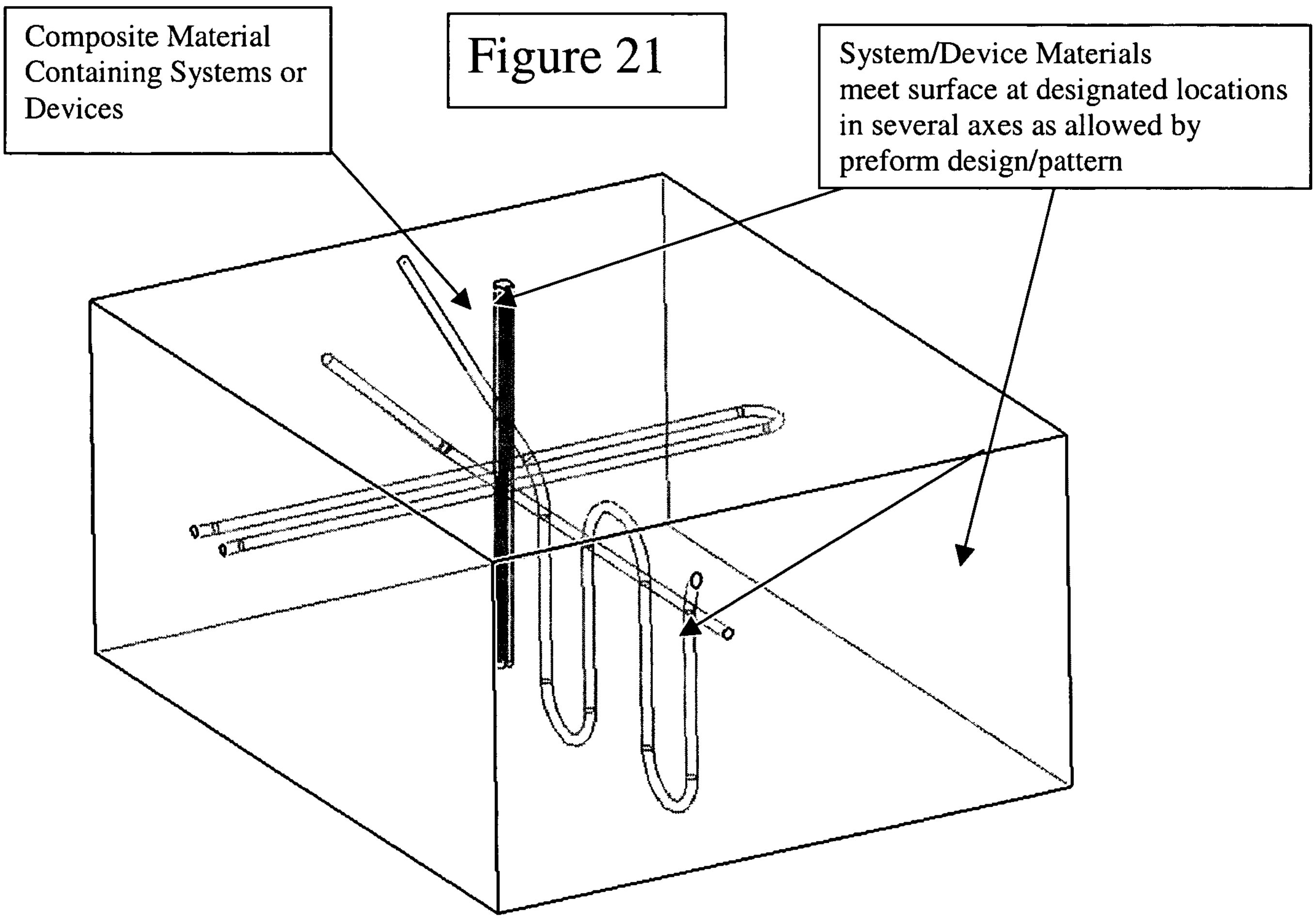
Figure 20



System/Device Materials Integrated during Preforming Emerge in Dangling Fashion from Composite According to Design.

FIG. 21 is a perspective illustration of one embodiment of the present invention wherein integration of system/device materials in the regular host material supply lines so as to be interwoven with the host materials preform carries the functional benefit to a composite manufactured using the fabric as a preform. Note that the base fabric material is not shown for clarity. The composite may be manufactured by various means often employed with textile preforms including but not limited to Vacuum Assisted Resin Transfer Molding, Reaction Injection Molding, Resin Transfer Molding, Resin Film Infusion, Pultrusion, and Hand Lay-up. Production of various metallic, ceramic, or other inorganic and high-temperature composites may utilize the same preforms where the constituent materials are chosen for these applications. The illustration shows several of innumerable paths, intersections, or patterns which may be achieved toward achieving the desired function. In this particular embodiment the system/device materials meet and are terminated or trimmed at both the preform and the subsequent composite according to functional preference, such as for their physical protection.

Figure 21



System/Device Materials Integrated during Preforming Meet Surface of Composite for Access According to Design.

FIG. 22 is a perspective illustration of one embodiment of the present invention wherein system/device materials are integrated in a plurality of locations along the natural paths of the host materials within a 3-D Braided fabric. Embodiments which make the complex pattern imposed by the 3-D Braiding process on the braider yarns allows for a wide range of placement and orientation options with flexible system/device materials, while integration along axial yarn paths which are straight by nature are preferred for rigid system/device materials due to the ease with which they may be bulled through or followed with a needle or other suitable device and because the straight paths allow the rigid materials to remain straight.

Figure 22

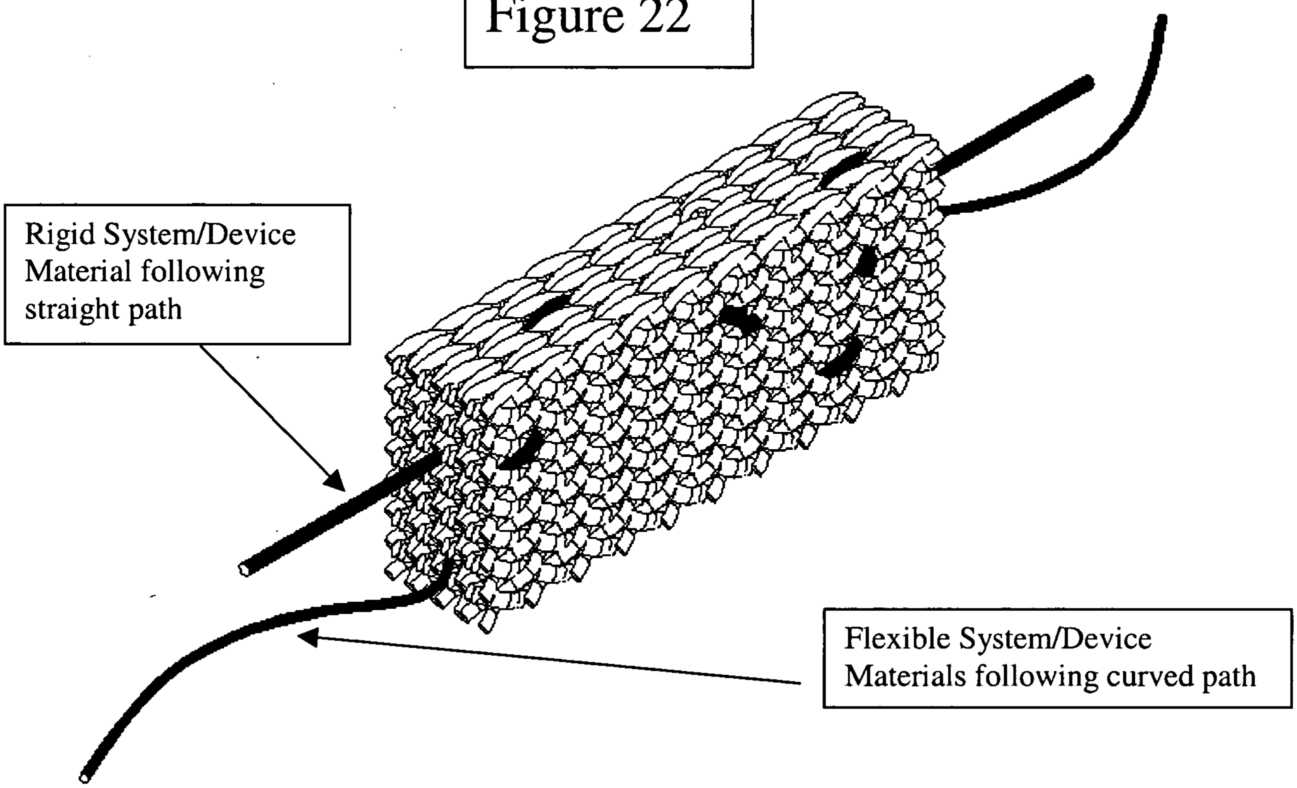


FIG. 23 is a perspective illustration of one embodiment of the present invention wherein system/device materials are integrated in a plurality of locations along the natural paths of the host materials within a 3-D Braided preform in the shape of a T-stiffener structural element. Embodiments which make particular use of this particular shape or similar complex cross section structural components, include but are not limited to instrumented pipes, box-beam spars, I-beams, shape changing rib stiffeners, or communications systems down the length of a large structure reinforced with a stiffener. The complex pattern imposed by the 3-D Braiding process on the braider yarns allows for a wide range of placement and orientation options with flexible system/device materials, while integration along axial yarn paths, which are straight by nature, are preferred for integrating rigid system/device materials due to the ease with which they may be bulled through or followed with a needle or other device and because the straight paths allow the rigid materials to remain straight.

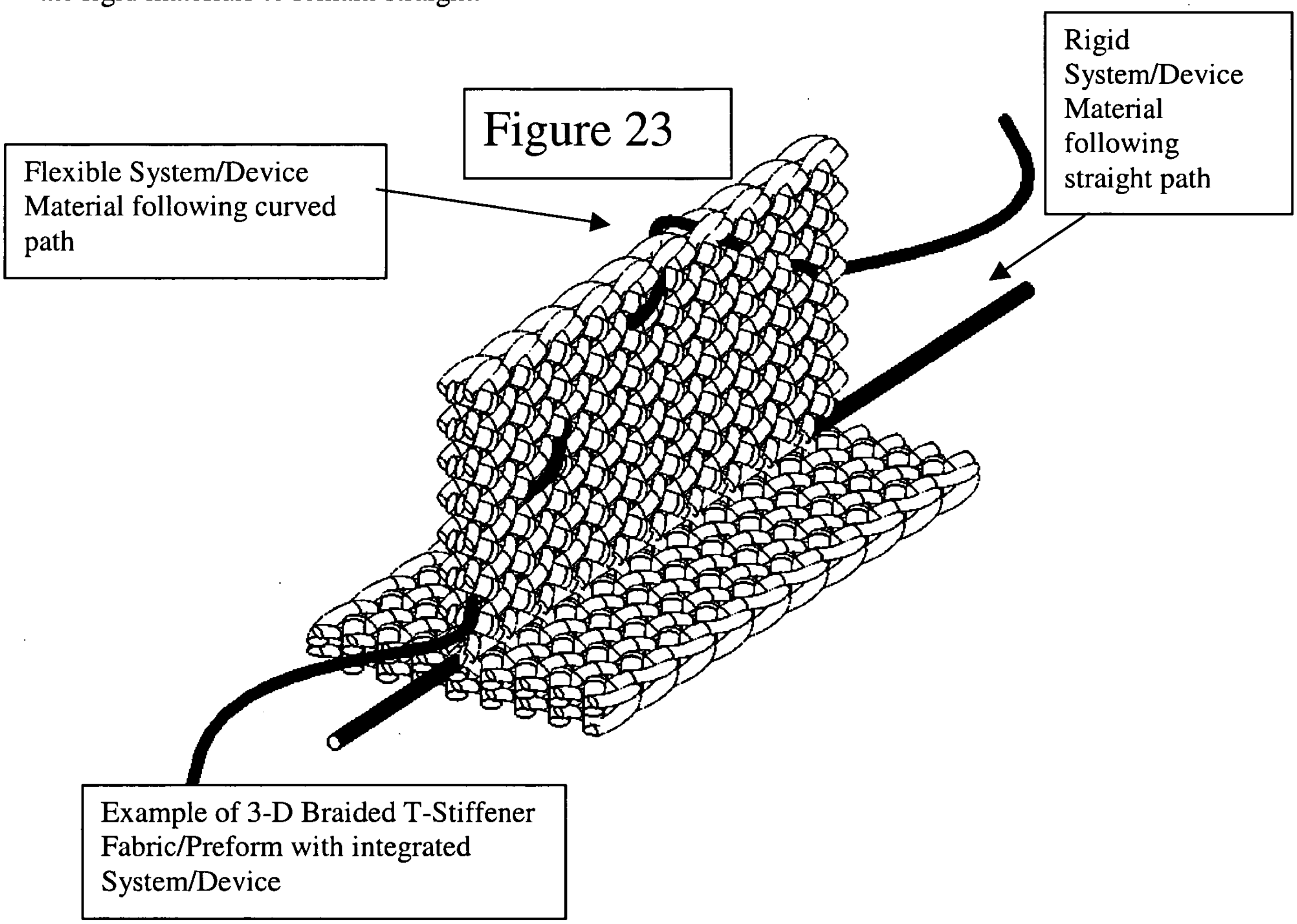


Figure 23

FIG. 24 is a perspective illustration of one embodiment of the present invention wherein system/device materials are integrated in a plurality of locations along the natural paths of the host materials within a Multi-Axial 3-D Woven fabric architecture. The minimal crimp applied to all in-plane yarns allows for placement and orientation of a wide range of flexible or rigid system/device materials because the straight paths allow the rigid materials to remain straight.

Figure 24

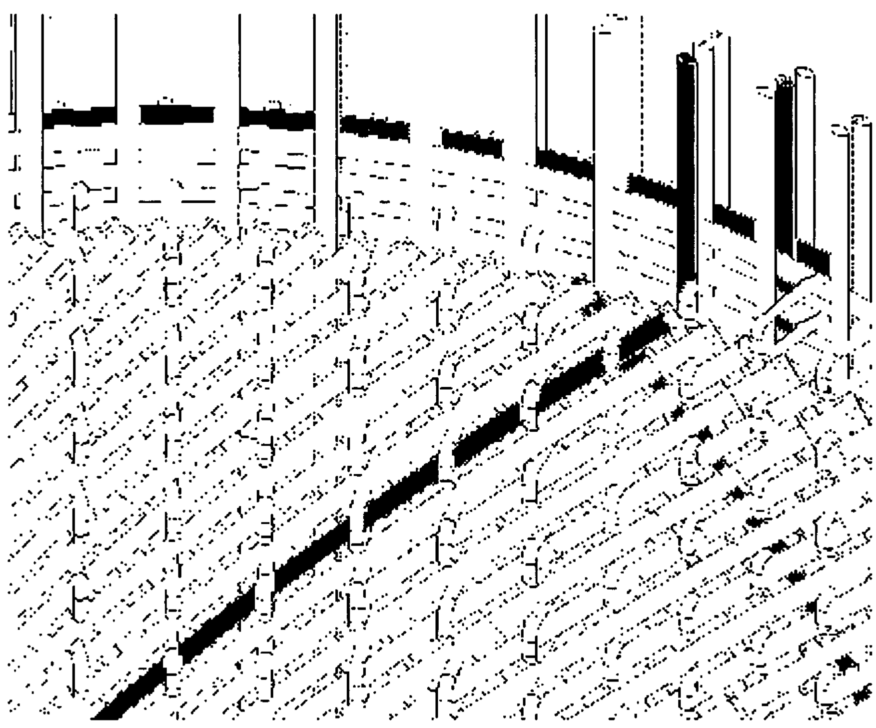


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FIG. 25 is a perspective illustration of one embodiment of the present invention wherein system/device materials are integrated in a plurality of locations along the natural paths of the host materials within a Multi-Axial Warp-Knitted or Stitch-Bonded fabric architecture. The minimal crimp applied to all in-plane yarns allows for placement and orientation of a wide range of flexible or rigid system/device materials because the straight paths allow the rigid materials to remain straight.

Figure 25

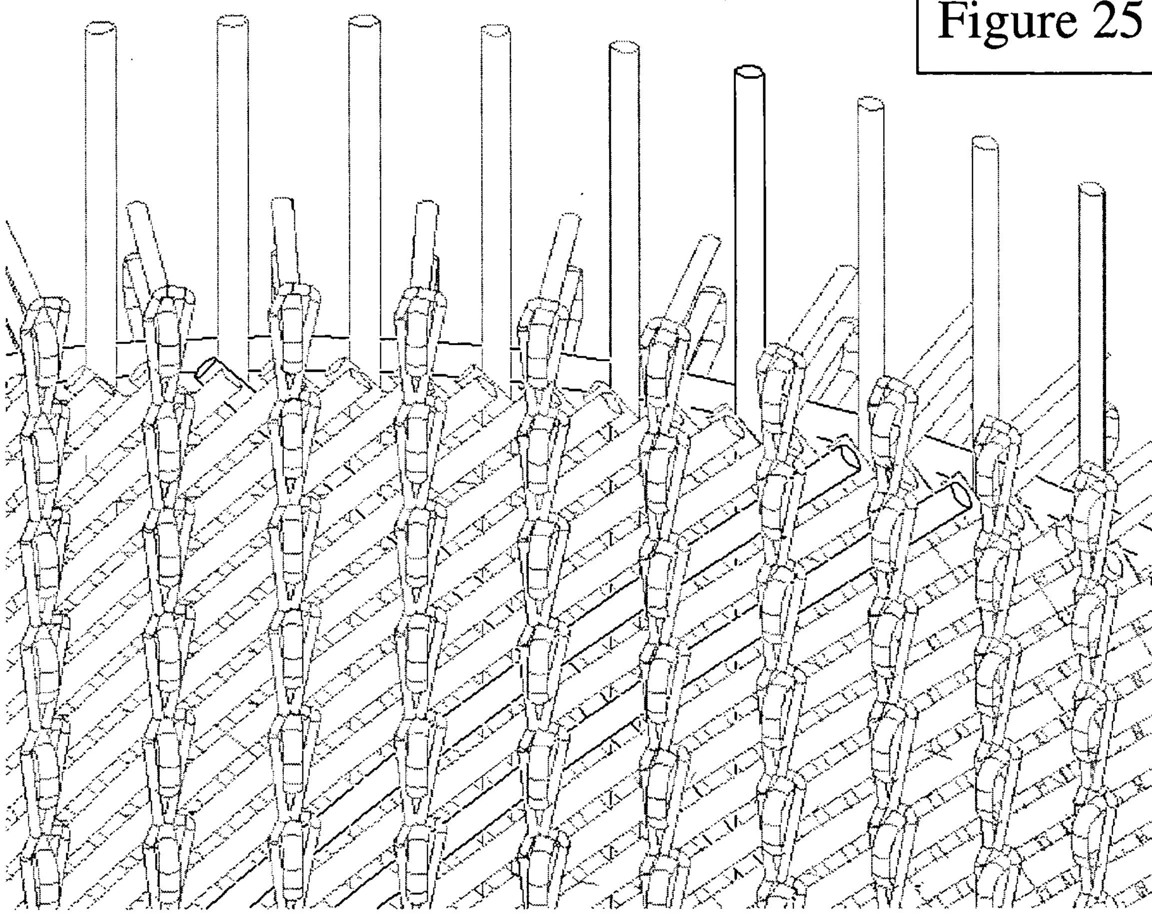

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Figure 26 is a schematic illustration of the introduction of system/device materials to the supply systems for any of various textile fabric formation system in order to achieve automated integration of the system/device materials into the textile fabric/preform. This may be accomplished in both a substitution or addition fashion and the system/device materials may be merged with or added to the supply at any point in the process up to, and including, the moment and location of fabric formation.

Fig 26

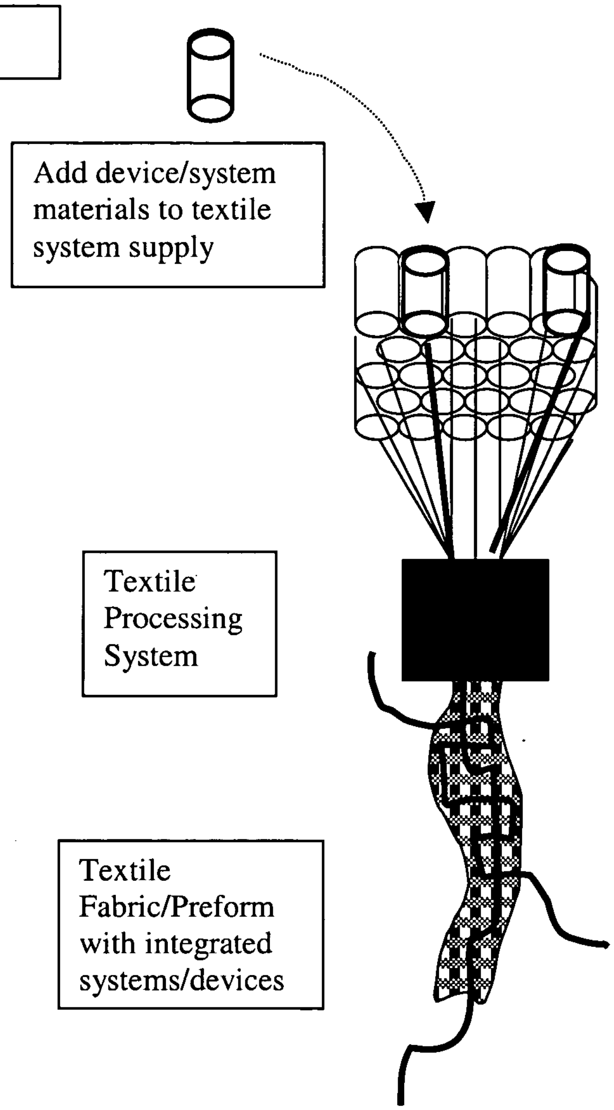
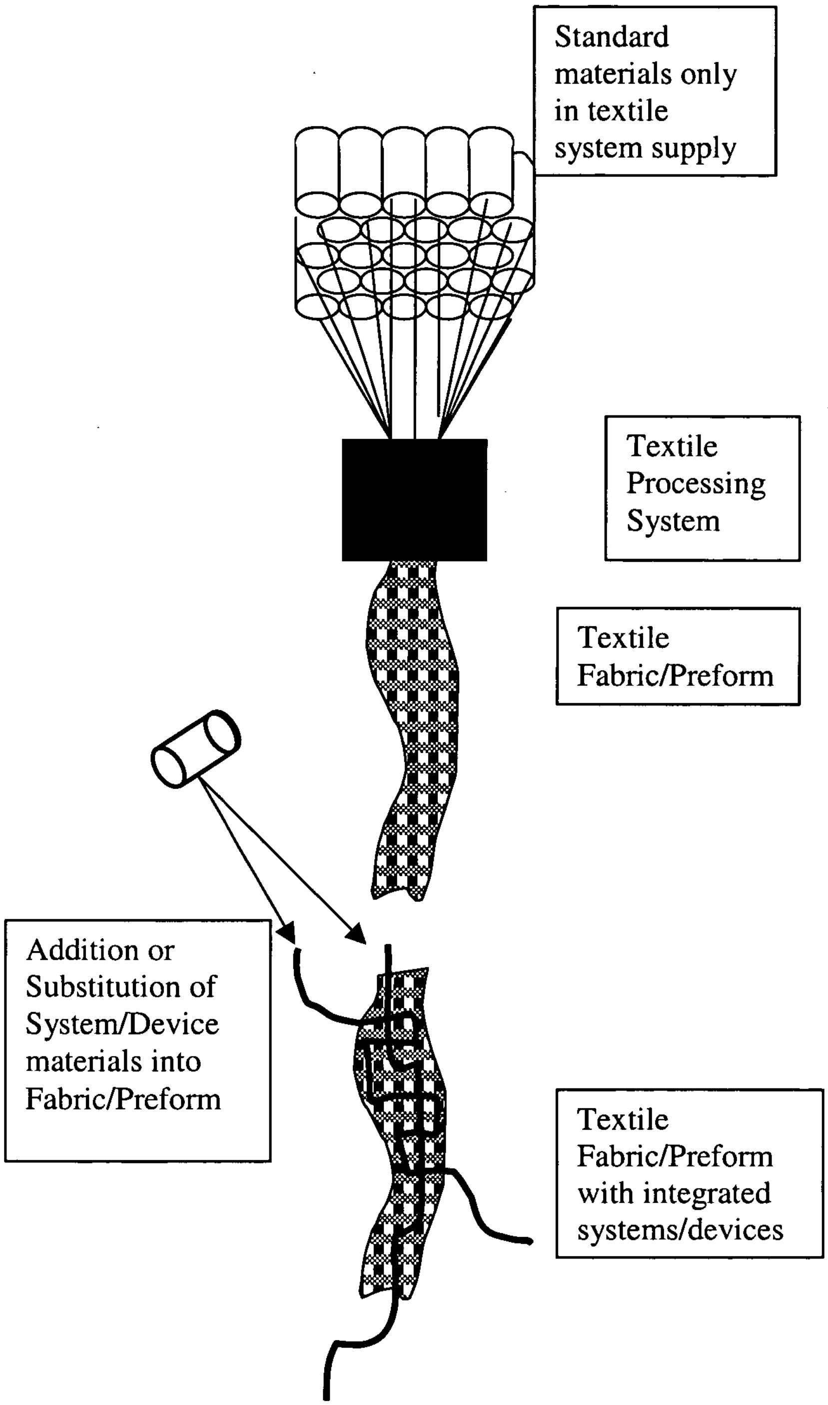


Figure 27 is a schematic illustration of the introduction of system/device materials to the textile fabric/preform after initial formation. This may be accomplished in both a substitution or additive fashion and the system/device materials may be rigid or flexible.

Figure 27



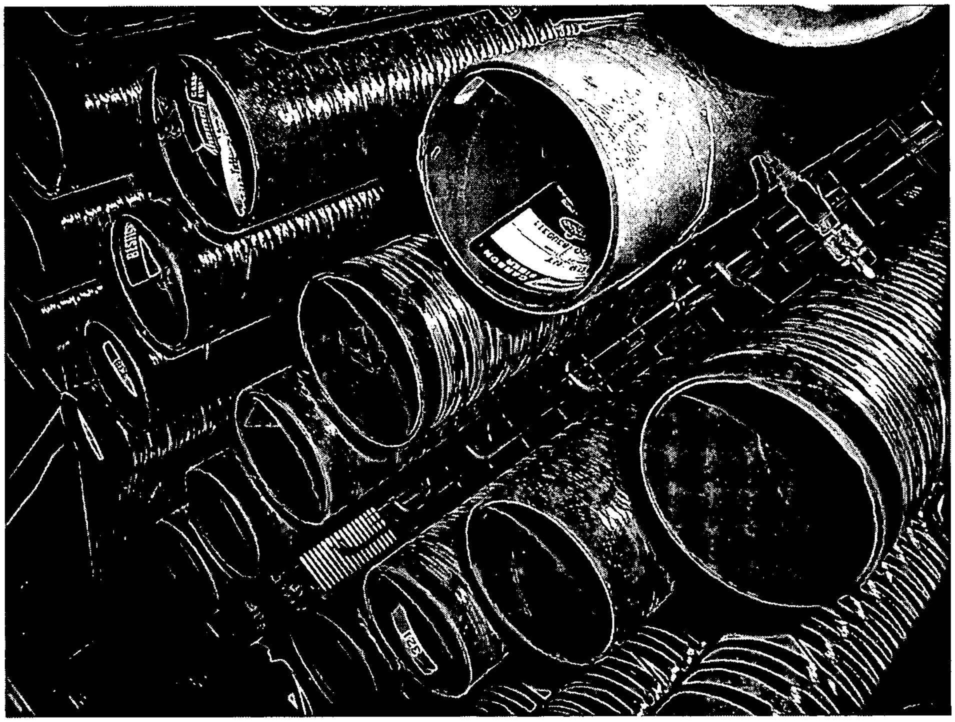


Fig. 28

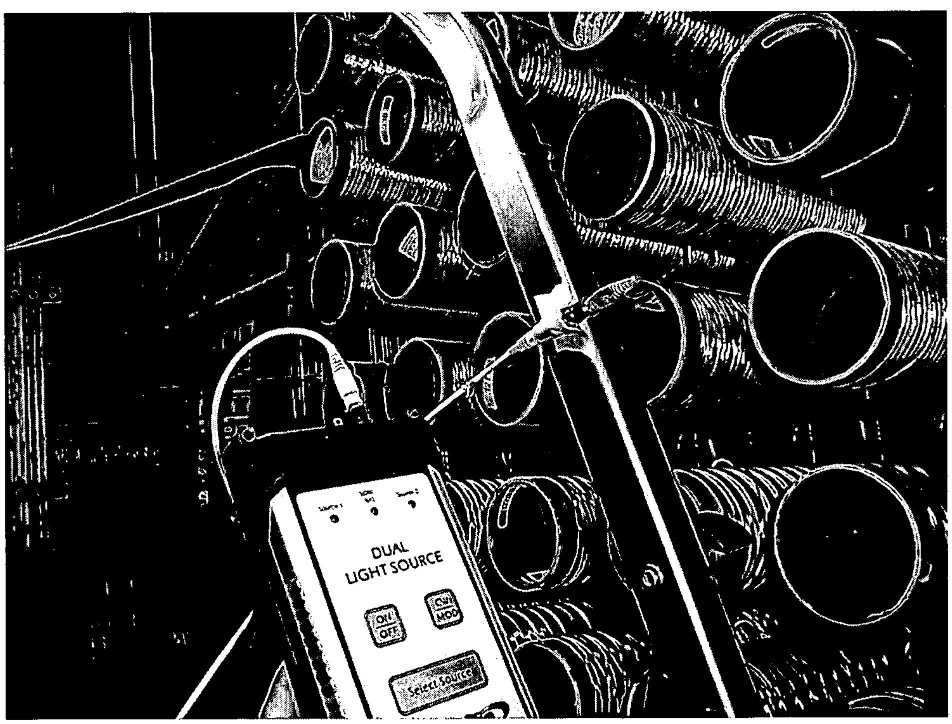


Fig. 29

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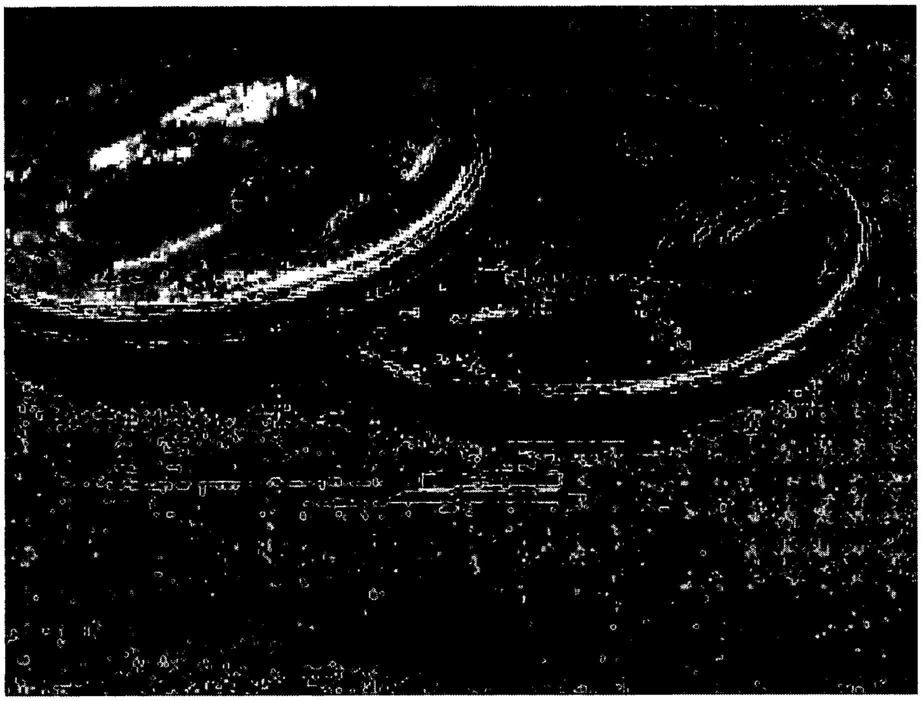

Fig. 30

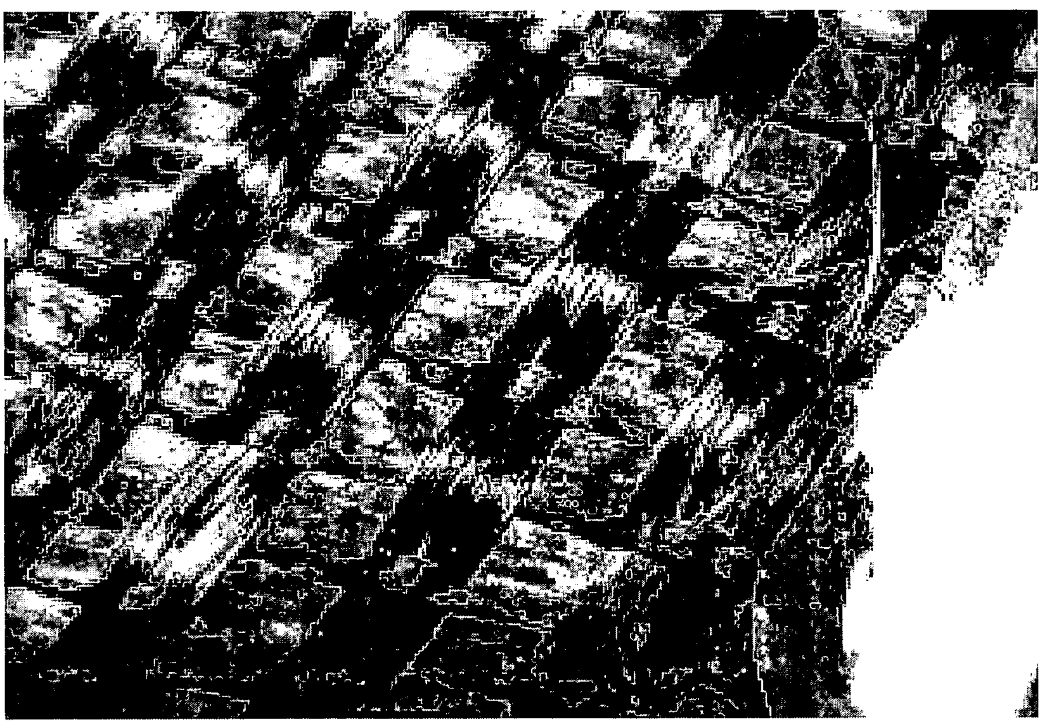

Fig. 31

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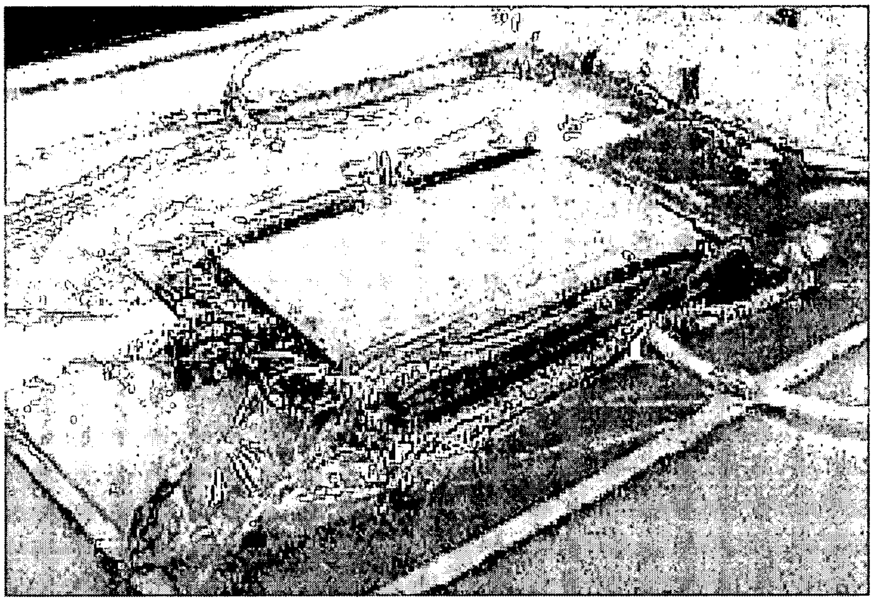

Fig. 32

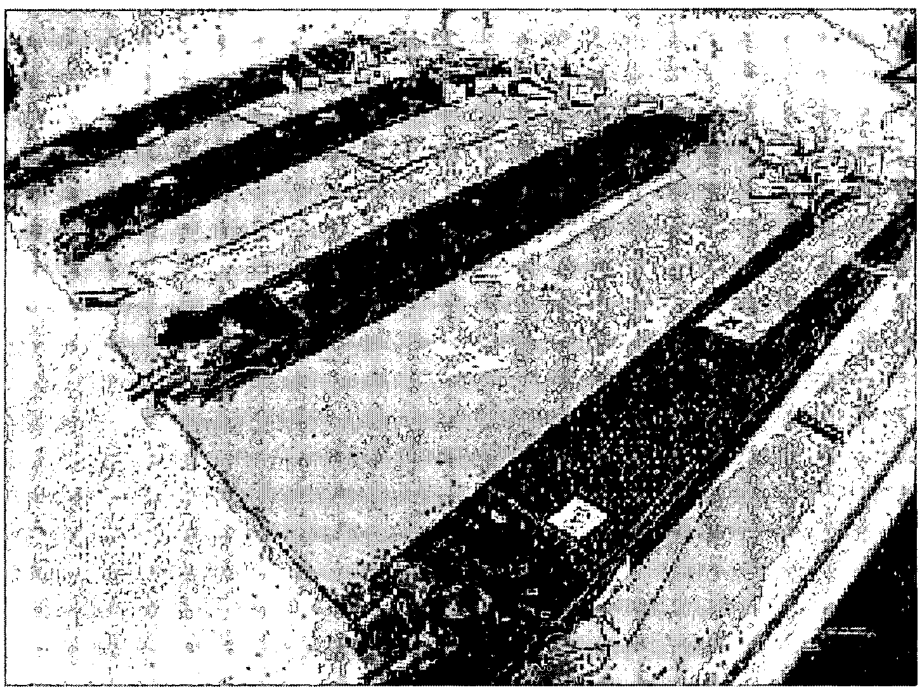

Fig. 33

Fig. 34

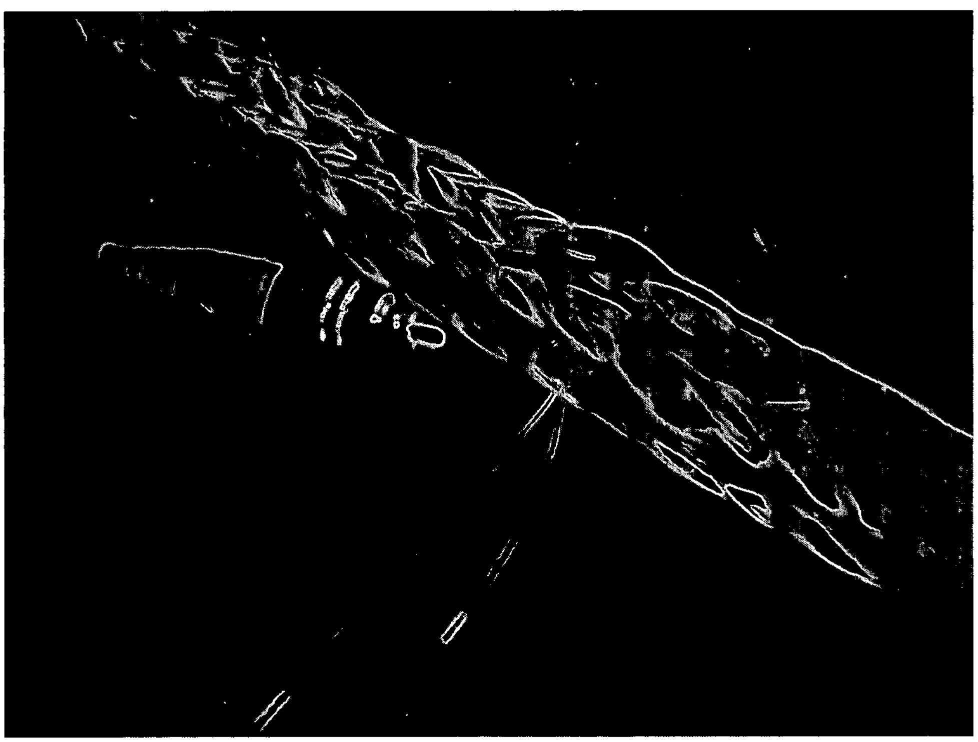

Fig. 35

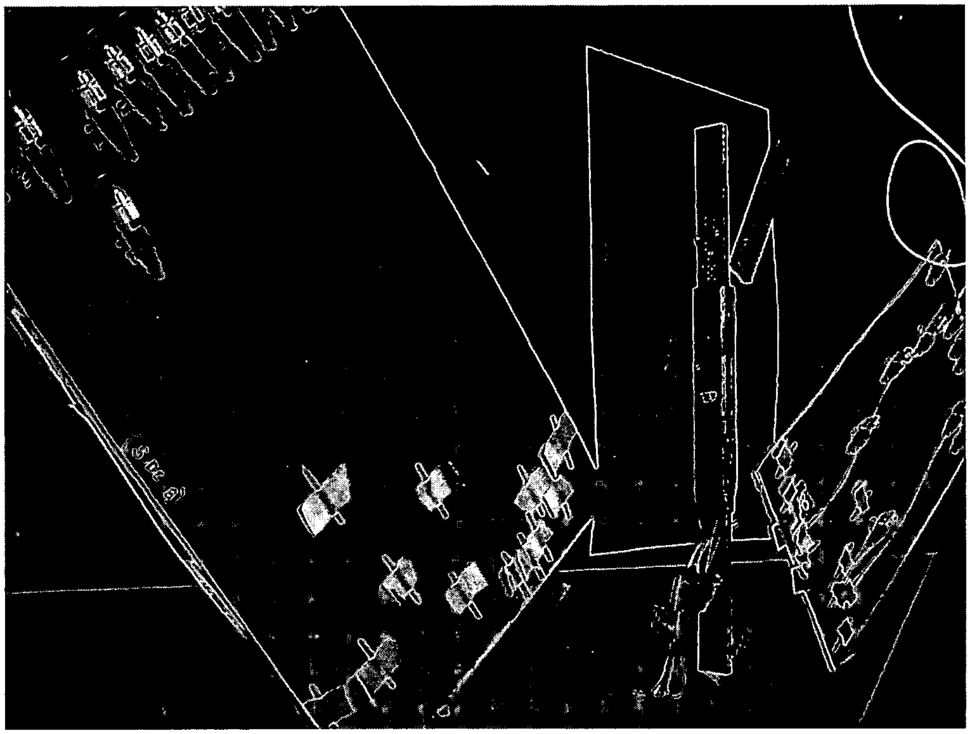

Fig. 36

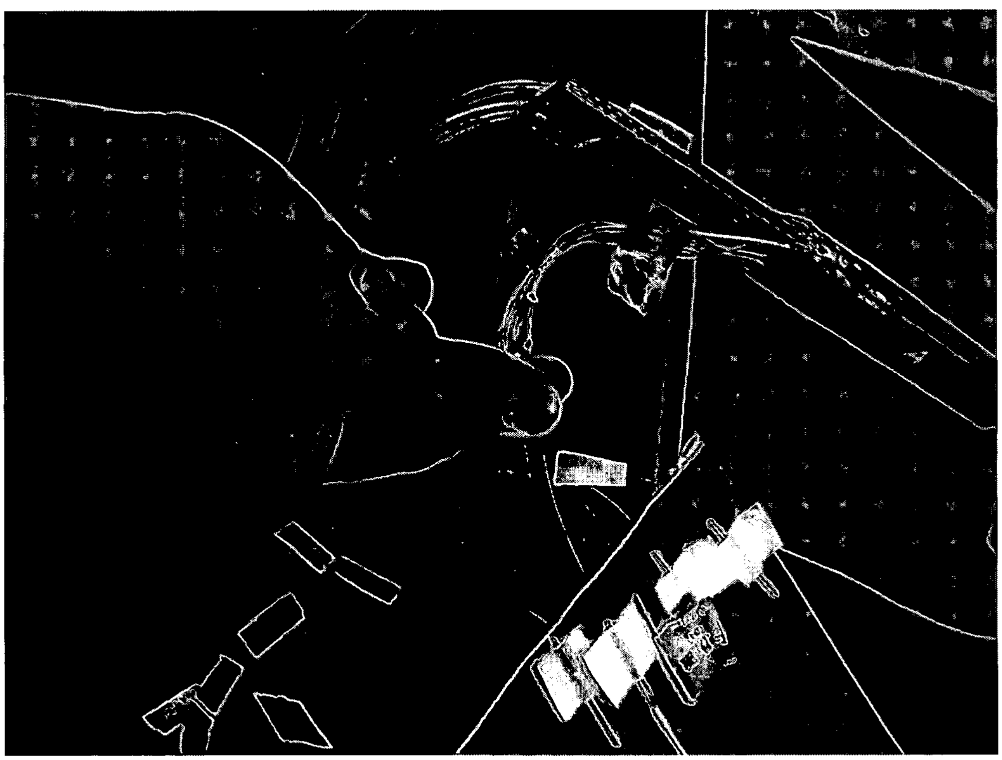

Fig. 37

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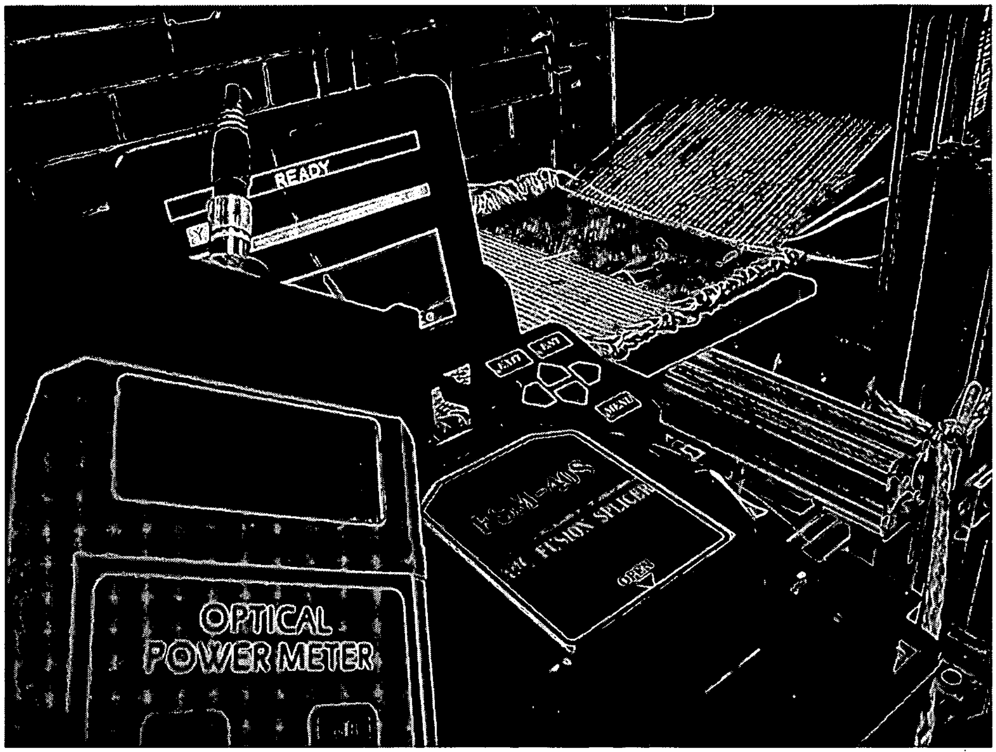

Fig. 38